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EDITORIAL NOTES.

Annual Meeting of the Institution.

THERE was an almost indefinable perfection about the annual meeting of the Institution of Gas Engineers last week. A conference of the kind cannot justify such an estimate without the presence of all the essential qualities. They were there—seen, felt, and appreciated, and producing an enthusiasm which allowed of no signs of weariness, though the programme on two of the days claimed morning and afternoon sittings. And this despite the temptations of bountiful weather and outdoor attractions within easy reach of London. What were the qualities? In the first place, there was the personality of the President, the Engineer and Manager of the Nottingham Corporation Gas Department. Plain, frank, and practical in word and deed, he says and does the right thing in the right place. He has the gift of combining cheerfulness with dignity. Both those attributes were used in the direction of the proceedings, and thus contributed to their wealth in productivity. Efficiency in a President is as important to the success of a meeting as efficiency in a gas engineer and manager is to the success of his undertaking. Some of us have had association with Mr. Wilkinson for many years. We have known of his reserve in public meeting; known him as a shrewd thinker and diligent worker; known him as a good friend and companion. We know more of him to-day after his tenancy of the Institution Chair; it gave opportunities for dipping deeper into the reasons which enable his Chairman (Sir Albert Ball) to speak of his services to Nottingham in the way he did at the opening sitting.

But we cannot give the Presidential influence all the glory for the excellent qualities of the annual meeting. The attendances, and their maintenance, at the sittings were excellent. The personnel and characteristics of the gas profession are slowly but markedly changing. The men of the past—those who have left us—were enthusiasts within the limits of knowledge and the nature of operations. But internally affairs have vastly changed, and so has our environment. There are greater claims to-day upon the men of the industry; and they have risen to meet them, and are preparing for an intensification. Everything points to a faster pace in evolution, and to the need for advances in methods. The Presidential Address, the reports of Committees, and the papers were alive with the indications of change and claim, and the remarkably high standard of the discussions is proof of active interest and study. Although there are some men who take change as it comes—who hardly perceive its coming, and show no clear appreciation of it when it is here, or evince little ability in interpreting its meaning—they are fortunately of the few; the major part of the men of the industry realize that wonderful headway in its affairs has been made, but that inside and outside the industry there are the portents of more and more development, which will have to be accepted and utilized in our own interests, or (if threatening) be met wisely and diplomatically, aided by the weight of all the technical and commercial efficiency which can, through science and experience, be introduced into our practices. It is such recognition which makes us, almost universally, desire to learn of work aiming at new achievement—work such as was presented in the reports and the papers on this occasion—and therein is another explanation of the success of the meeting. The industry is fortunate in its men; the men are fortunate in having an industry of such scope and fertility in which to work for progress. The present position of progress as adumbrated in the written and oral statements at the meeting show how the efficiency of our plant and methods have been raised through laboratory and works explorations, and through the inventive skill of our manufacturers of plant and appliances. Yet the proceedings last week evidenced the confidence that there is much more to be gained and applied, and that to gain more for application is worth much effort, time, and expenditure. There is a traditional assertion—call it libel if you will—that the gas industry is ultra-conservative in its attitude to new methods. There may once upon a time have been some truth in this; but the meeting has given us the impression that such an attitude is fast disappearing. The desire to do better, and to serve our time and generation well, is growing. At the same time there is no wish to stop genuine progress in other directions; but in that progress there is every incentive to cause our own service to attain better state, and through it to protect our interests.

Thus presidential attributes, the quality of the papers, reports, and discussions, the mutations (actual and possible) within and outside the industry, the interest, keenness, and ambitions of the members, and their attendance are the factors which—separately and in combination—produced the magnificent success of the meeting last week. We congratulate heartily the President and the Council, and all who contributed in any way to the fine result. And we hope the widespread satisfaction among his colleagues which Mr. Wilkinson can contemplate will have its repetition in the presidential year upon which Mr. H. D. Madden, of Cardiff, has now entered. Our best wishes to him, we are sure, are but the representation of those of the members generally. Mr. Wilkinson had a period of peculiar trial and difficulty through the coal strike; Mr. Madden enters upon his duties in a year which promises industrial peace. The opportunities for constructive endeavour will be greater this presidential year than they were in the past one; and the changes which we see about us will during the year develop, and take clearer form. There are difficulties ahead. But they are not only difficulties; they are incentives.

The social side of the meeting was most enjoyable. The reception and dance at the invitation of the President and Mrs. Wilkinson was an occasion of unadulterated pleasure. The visit to Nottingham on Friday was an unalloyed success, as it was bound to be with as the hosts Sir Albert Ball and his colleagues of the Corporation Gas Committee, his Worship the Mayor, and councillors generally. The interest of the city was spread freely before the members and open to their inspection; and this, with the geniality and hospitality of the hosts, will be among the abiding memories of those whose good fortune it was to be there.

The President on Changes in Condition.

TIME brings its changes to all; even well-established industries do not escape. It has brought changes in the internal affairs of the gas industry; we have also our problems due to mutations in environment. They affect conditions and values; and they have to be kept under close scrutiny, so as to enable us to proceed in right directions. The Presidential Address of Mr. John Wil-

kinson draws attention to certain of these changes, and to problems to which they have given birth. He has focussed them well, though there is no pretence to completeness, but only exemplification.

Right in the forefront of the address, acknowledgment is made of how the decisions of the Joint Industrial Council have helped the gas industry in the time of national labour troubles, and that, through those decisions, there has been a better blending of the interests of those who serve and of the industry itself. This condition, always valuable, was more so during 1926. Our industry, however, is not solely dependent upon its own labour. The actions of labour external to it can and do inflict upon it and the community extraordinary injury. Last year proved this. Therefore outside labour developments and policies (which the President eschewed) are matters with which we must keep in close contact. The federation of labour, which enables mass movement involving several industries (a matter with which the Trade Disputes Bill is intended to deal), has grown to such an extent that it has upset all our notions as to what are correct precautionary measures to take to enable us to carry on through a disturbance or stoppage of supplies. After the destructive demonstration of labour endurance which the country had last year, it is impossible for anyone to say positively what is an absolutely safe stock of coal for a gas undertaking to provide. The President asked the question; but reply is not forthcoming. He does, however, say there is an economic side to the question, and therefore a limit to the stock we can carry without bringing into effect a visible increase in the price of gas. It would thus appear that gas undertakings must still continue to take risks, and be prepared to face the strain of any prolonged coal stoppage which may occur. There again, it is possible to argue that seven or eight months' coal stock (if practicable) would last year have shown somewhat extraordinary economic consequences for any undertaking, compared with the outlay which had eventually to be incurred; and it may be that the industry will stand great risk should anything of the same kind happen again, if it rests content with slender stocks, in the confident belief that help will come from other countries. Labour development is extending internationally; and due weight must be given to the President's remark: "The slogan 'Unity is Strength' appears to be so easily construed into 'Might is Right!'" However, this is a matter which can only be subject to commonsense judgment in the light of past experiences. Touching upon the conditions within the coal industry, the President has lived in close contact with it for many years; and he makes a suggestion which, to his mind, would bring greater contentment to the mine workers (if practicable) by arranging a longer working day during the winter months when the demand for coal is greatest, and a correspondingly shorter one during the summer months, with adjustments of the basic rates of pay to meet the varied conditions. We commend this suggestion to the consideration of those in the coal industry who are better qualified to discuss it than we are.

On the part of the President there is no sympathy with those in the coal industry who, with traditional insistence, state that gas undertakings do not pay economic prices for their requirements of coal. He heard this story the first time he negotiated a coal contract; he heard it when he negotiated his last contract. The regularity and magnitude of the custom of the gas industry should claim and obtain special consideration in the matter of coal prices; but we are constantly hearing talk of pressing for higher ones. To any actual movement in this direction, there would be strong resistance, as there would be to any recognition of the principle that, as gas has so largely displaced coal for domestic purposes, the price of gas coal should be increased proportionately to the loss sustained by the coal industry. A much better line of consideration for the colliery owners is the suggestion of the President that the success of the coal industry depends mainly upon the average price realized for all grades of coal. He instances the cost of the production of slack which does not justify its being sold at a lower figure than cost. Yet though there may be little difference in the calorific value of slacks as compared with gas coal, electricity undertakings are to-day purchasing them at several shillings per ton below the payment by the gas industry for its coal requirements. With the increasing demand for slack for steam-raising purposes, it is time colliery owners made slack bear its full proportion of production costs.

All the foregoing applies more or less to important external changes which have made their impression upon the gas industry. Coming to our inside technical affairs, the President is one of those who realize fully that we have not yet reached the Ultima Thule in carbonization knowledge; but he is not in accord with those who say that, in our carbonization processes, we have not advanced beyond the original stage. Fundamentally carbonization remains much the same as at the beginning. But it has developed in every detail; and the sum of detailed development shows remarkable progress, to which contribution has been made by the change from the illuminating power to the calorific value standard. Looking back over old records, the President finds that in 1819 the average make of gas per ton of coal carbonized at Nottingham was 8015 c.ft.; and he calculates that its calorific value was probably 700 B.Th.U. per c.ft. gross, or 56·1 therms per ton. Using horizontal fireclay retorts, instead of cast-iron ones, 72 therms of coal gas are now obtained, which means an increase in thermal efficiency of 28·34 p.ct. With continuous vertical retorts, an additional 8 therms are realized, which enables the claim to a total increase in the thermal yield in gas alone equal to 42·6 p.ct. That is a representation of the advance made. The President is not prepared to say that this is the maximum economic limit; but even if it is, in his view it provides substantial security for the future of the industry.

Before calling attention to the efficiency just mentioned as having been realized in vertical retort working, the President, speaking of horizontal retorts, asks three questions: Is the increase in thermal efficiency satisfactory? How has it been attained? Can it be improved? These are important questions; but to the first he does not give a direct answer—in fact, he confesses that he is at present "sitting on the fence." When, however, one considers what follows in the address, it is fairly clear that, in the President's view, judging from the standpoint of existing knowledge, in high standard working with the horizontal retort the maximum thermal efficiency in respect of gas has been about reached, unless, of course, we are prepared to make sacrifices in other directions. The answer he gives to the second question justifies this deduction as to his view, as he says the increased efficiency with horizontal retorts has been obtained by the application of higher heats, and the higher thermal yield has been realized by the permanent gasification of a portion of the tar. It is in connection with tar that he discusses the third question—that is, whether tar can be treated more or less successfully (according to the character of the plant employed) for the production of permanent gas. But the result is that, though materials may be found which will stand higher carbonizing temperatures, there is a limit to the heat at which coal can be carbonized for purely gas-making purposes. Hence he is of opinion that, if it is proved that the permanent gasification of tar is a profitable operation, it will eventually be done in ancillary plant.

Of course, the economic limit in the production of gas per ton depends largely upon the future of the market values of the secondary products. Enlarged competition with our secondary products is not only possible, but certain. Its advance guard is already at our gates, taking away business. It may, therefore, be that the time will come when there will have to be complete gasification of, at any rate, part of the coal the gas industry uses. As the President remarks, enterprising coke-oven managers have tested their ability to compete in the gas coke trade, and yet gas undertakings have the advantage of their local situation. Furthermore, there is the constant endeavour of the advocates of low-temperature carbonization also to get into the domestic fuel market. This being so, it is good advice the President gives—that it is up to gas undertakings to do their utmost to retain the local market by producing coke of good quality, as free from ash and moisture as circumstances will allow, and to sell it at competitive prices. On the point of quality, it is significant—as pointed out in the address—that, when higher heats were first applied in horizontal retort working, there were more complaints from consumers of coke than had previously been experienced; and justification

for it was found in its greater density and lower volatile content. But vertical retort coke has helped to prove that it is more a matter of structure than volatile content which makes for good coke for domestic purposes. Consumers have shown a preference and even avidity for vertical retort coke, although it does not contain more volatile matter than the horizontal brand. Structure and lower moisture content are the qualities which enable it to burn more freely than the high-temperature horizontal variety.

The competition that has come, and will come about with still greater force, in our coke market is a change of considerable importance to the gas industry, and one which must not be neglected. The same applies to tar. The changing circumstances need investigation. The greater the patronage by the gas industry of coke-oven gas, and the more the coke-oven industry develops its business in the domestic coke market, the greater will be its output of tar. That is a consideration which should not be lost sight of by the gas industry. It means a larger supply being put upon the market; whether or not the demand will increase *pari passu* is an open question. Furthermore, there is the strong competition of bitumen for road purposes. In view of these changes—present and prospective—and having regard to the large expansion of the use of vertical retorts in the gas industry, no time should be lost in carrying out investigations into the question of a proper specification for vertical retort tar, so as to annul the objections which have been raised against it for road purposes. The President has a good deal to say on this subject. He does not deny that there is ground for complaint; but he does suggest, and we all agree, that there is nothing insuperable in the work of rendering vertical retort tar suitable for all and every purpose. He is desirous of preventing mere prejudice adversely affecting its value; but it must be remembered that prejudice usually has some substantial cause for its genesis. Therefore, he urges that research work into tar should be largely concentrated on that from vertical retorts. He deals also with sulphate of ammonia. There we have an imposing change. We all know what has happened. There is little prospect of materially reducing production costs; and synthetic ammonia bids fair to maintain the control of market values which it has indisputably gained.

In these and other directions, the address brings us face to face with changes which affect the gas industry, and which call for earnest consideration, and any necessary revision of procedure to meet the new conditions. In this connection, we all share the satisfaction expressed by the President regarding the constructive work that is going forward. There is hopefulness in respect of that of the National Fuel and Power Committee; confidence in that which proceeds at the Leeds University, and in connection with the Refractory Materials Research work. The beneficial and indispensable activities of the National Gas Council, the British Commercial Gas Association, and the Education Committee of the Institution are also brought into prominence by the President. Singly and in combination they reflect the great changes which have taken place within and outside the industry, and which have had, or may have, an important bearing upon it. The industry has been wise in promoting and maintaining bodies exercising efficient surveillance over its affairs, and operating for both advance and defence.

Carbonization and Coke Treatment—at Home and Abroad.

IT is significant that a large part of the reports and papers presented at the meeting treated of matters affecting carbonization, with special consideration of the production of gaseous therms and the yield and treatment of the chief of the secondary products. Apart from their complete reproduction in this issue, the contributions and discussions are briefly reviewed in later columns, with the view of indicating their trend. We believe that the Eighteenth Report of the Gas Investigation Committee, the Fellowship Report, and certain of the papers—such as those of Mr. T. Carmichael, Mr. G. M. Gill, and Mr. J. P. Leather—will accentuate the opinion of many gas engineers that we are within measurable distance of making—not perhaps revolutionary, but notable, changes in our practices in carbonizing coal and in treating coke. Anyway, we feel the idea is distinctly hardening that the ultimate has not yet been reached in these respects; and the very fact that work is proceeding with an eye to development is the best of indications that the view is held in the most competent of technical quarters. No one can yet say what will happen; but every year brings fresh light. Let us attempt to marshal some of the facts presented at the meeting.

Take first something which has been accomplished. It is long ago since we urged that greater investigation should be made of that vital element in carbonization—the long-neglected charge. The last few years experimental and practical attention has been given to it. At the meeting of the Institution last autumn, there was the evidence that higher efficiencies and economies are to be derived by a proper manipulation of charges. We then had the results of research in this direction by the Gas Investigation Committee, who this year supply further enlightenment. We also had the results of researches at Birmingham by Mr. T. F. E. Rhead, which prove how the separation of the dust and fines from coal used in verticals greatly improves the yield, while the screenings find their proper place in the horizontal retorts. We are reminded that Mr. Carmichael deserves credit in this connection for his earlier work at Portsmouth. He was engaged experimentally upon it (as a paper before the Southern Association shows) as far back as 1922; and the satisfaction given by experiment led to full-scale working. Probably the contractors for horizontal retorts will say that the method of working—the utilization in them of material which is rejected from vertical retorts to improve their efficiency—is unfair to horizontal working, and that each plant ought to be operated in the manner which will enable it to give the best effect without preferential treatment. But we have got past that argument. What has to be done nowadays is to realize the best of which the plant, irrespective of type and individual prestige, is capable in combination. It is the commercial result at which we have to look, and not solely the thermal efficiency of a particular plant.

However, since 1922, Mr. Carmichael has been screening his Durham coal—using the larger in vertical retorts, and the dust and fines in horizontal ones. The result is instructive. The production per ton of coal carbonized in the verticals rose from about 62 therms with the unscreened coal to 69·1 therms with the screened; while in a horizontal house, the total therms evolved dropped only from 70·2 to 68·8 therms per ton. Thus we see a gain by the verticals with screened coal of 7·1 therms, and a reduction of only 1·4 therms by the horizontals using the screenings, which leaves a net gain of 5·7 therms. The thermal output of the plant shows a more marked improvement—one bed of vertical retorts rising from 860 to 1032 therms per day. Thus, from all aspects there is a considerable gain in efficiency and economy. In the past, much has been heard of engineers having had indifferent experiences with continuous vertical retorts when using Durham coals, while others have not. Those who have not, have contended it was all a matter of temperature. It is perfectly obvious that if, with highly bituminous coal, the dust and fines (which make the charge of a more compact order) are eliminated, such coals have a better chance of giving the best possible account of themselves in continuous verticals, with or without steaming.

The Gas Investigation Committee's latest carbonization researches (with Dr. Parker as Research Chemist) deal further with the influence of the size of particles of the charge upon productive results; but the present report is a document containing much detail, which invites close study rather than brief and general comment. The work also includes an examination of the effects of mixing coke with coal charges—a matter which has frequently been referred to in our columns. But Dr. Parker has arrived at a different conclusion from that which has been put forward by some other workers. His conclusion is—and he is no doubt right—that the disadvantages which result from the admixture of coke with the particular coal used in the experiments more than counterbalance the advantages. The coal used was a Nottinghamshire one. But it is still an open question whether, in large-scale working, using a highly swelling coal, different effects would result from the admixture of a proportion of coke or non-coking coal—for example, more rapid and uniform carbonization,

and the production of a better coke. If more rapid carbonization would ensue from the admixture of coke with certain types of coal—by the breaking-down of the plastic layer, and the quicker transmission of heat through the charge—it would suggest that any loss of gas production there might be per charge would be compensated by the greater throughput in a given time. The same report deals with the mixture of coal with calcium carbonate, iron oxide, and sodium carbonate. The work that is being done in this direction in the Coal Gas and Fuel Department of the Leeds University is raising in the profession no small amount of curiosity. From the results of the experimental work, it is seen that the added ingredients give an increase in the volume of gas made, but the gas is of a lower calorific value. There is, however, an increase in thermal value, a reduction of sulphuretted hydrogen, and an increase in ammonia yield.

Let us get back to matters affecting the immediate future. There is the question of coke quality. It has been proved over and over again that coke from vertical retorts has gained considerable favour as a domestic fuel. It is lower in moisture, more easily ignited, and contains less ash than coke made from unscreened coal or screenings in horizontal retorts. Mr. Carmichael finds that in his vertical coke from screened coal, the proportion of ash is 11·6 p.ct.; from that in horizontal retorts using screenings 16·3 p.ct.—a difference of 4·7 p.ct. That is important. We shall be compelled, by circumstances and commercial wisdom, to reduce the ash in coke to as low a figure as is practicable. This also applies to moisture. We have had good experience now of the greater value placed by domestic consumers (who are the masters of the situation) upon the drier vertical coke, which only requires, after it leaves the retort, modest (if any) finishing quenching. The coke is less damaged than is coke quenched by heavy watering. The sudden dousing causes disintegration, spoils appearance, and diminishes reactivity; and no good is done by the process to the iron or steel work in the neighbourhood. A coke containing 10 p.ct. of moisture is that much short of heating material; and some of the carbon has to be utilized to drive off the moisture before the coke does effective work. In his paper, Mr. Leather calculates that 10 p.ct. content of moisture in coke depreciates the heating value by 11 p.ct. It is therefore time that greater attention was given to dry methods of cooling. The object of Mr. Leather's paper was to give a descriptive account of dry processes—such as that practised at Liverpool, the Sulzer, the Collin, and the Heller-Bamag—and his clear exposition of the features of these enables ready appreciation. But we should like to know more about the costs. The utilization of the heat of the coke in these processes is a feature upon which Mr. Leather dwells, and which should be considered in connection with waste-heat boilers, inasmuch as recovery of more heat than a gas-works needs for its own steam requirements might, after all, bring to reality the dream of some engineers of gas-works becoming tributaries to the country's system of electricity supply. Mr. Leather's paper is useful in that it opens up in a definite manner consideration of processes which improve the value not only of the incandescent coke discharge from retorts, but the effective utilization of the otherwise wasted heat. Coke improvement is a matter which forces itself as imperative, however accomplished. The protection of our coke trade must be taken into account in considering the question of the cost of a dry quenching process.

The reports of the Gas Investigation Committee are getting more valuable, particularly in regard to the gasification and reactivity of cokes. Dr. Parker's report, as we have already seen, deals with the question of mixing with coal calcium carbonate, iron oxide, and sodium carbonate. The Fellowship report on the gasification of special cokes made by the addition of such inorganic constituents carries information some steps further. It has already been shown by these researches that the additions of various oxides to the extent of 5 p.ct. have a marked influence on the rate of gasification, and on the quality of the water gas made. The new work has demonstrated that smaller quantities of these constituents have also a marked effect, which finding is important from the economic point of view. Some of the first experiments were concerned with the stimulating effect of the ash constituents on reactivity in steam, but the important question of the reactivity in carbon dioxide and reactivity with air have now been under investigation. The report supplies a large fund of information for students of these matters who, like ourselves, are being persuaded by developing knowledge that we are not a great distance from a reconstruction of carbonizing practices.

Incidentally, the question of competition from coke-ovens was brought before the members in Mr. G. M. Gill's paper, which supplies a highly interesting description of various types of oven which he has had an opportunity of inspecting in operation. As he says, oven coke is suitable for all purposes excepting open grates, for which gas coke is employed; and this fact, combined with the development of the domestic coke-boiler, has altered the whole question of coke sales. Oven coke can be burned quite satisfactorily in the house boiler—just as well as (say) horizontal coke. That must not be overlooked, when building hopes on the coke-boiler providing a good and permanent market for gas coke. Coke ovens are largely used in American gas-works; and it is plain that Mr. Gill is of opinion that large gas-works in this country will come to use them on account of their flexibility, the range of coal which can be treated in them, and other advantages. While admitting that ovens have intrinsic advantages in some situations, a point upon which most gas men will largely concentrate will be: Can a gas therm be produced with them for less cost than in the case (say) of continuous vertical retorts, or high-class horizontal working? Take, for example, figures given in Mr. Carmichael's paper. Looking at Table III., it is seen that, in the final comparative costs—calculating coke at 30s. per ton, and under the other conditions mentioned in the paper—the best vertical retort installation at Portsmouth, working on Durham coal (stock), with steaming, gave a net total cost per therm of 1·67d., while the best for horizontal working with Durham unscreened coal was 1·69d. Even with Durham screenings in horizontals, the cost per therm is only 1·72d. The question is, Can coke-ovens, in conditions similar to those existing at Portsmouth, produce gas therms at lower figures than these?

One other contribution to the proceedings which touched upon carbonization is the report of the Refractory Materials Joint Committee. The Committee have accomplished much (as Mr. Carmichael said in his paper) in advancing the general standard of refractory materials; and makers of all classes of such materials have met the demand for higher quality in a very satisfactory manner. Nevertheless, there is still room for improvement, especially with regard to the constitution of the silica portions of carbonizing plant to allow of correct expansion. From the Committee's report it is seen that they have had under consideration the clauses of the Standard Specification dealing with the test for the after-expansion of silica material: but, in the present state of knowledge, it is inadvisable to make any change. There is a prospect however, of a series of tests being carried out on a variety of silica bricks, so that in time information, of which there is a deficiency at present, may be available which will enable the modification of the clauses dealing with the test. It is also hoped that good will issue from the request which has been made to the Research Association for a report on the present position of knowledge relating to materials suitable for the insulation of retort benches. We want to save all possible thermal losses in our carbonization plants.

All these matters declare persistent effort in the endeavour to elicit from present conditions information which will raise still further our carbonization practices and standards.

Other Topics.

In the preceding article, reference is made to the majority of the contributions to the technical proceedings at the meeting. Items which are not noticed are the Report of the Advisory Committee on Education, which was presented by the Chairman, Mr. F. W. Goodenough, the paper by Mr. J. H. Canning on "Some Experiences of Gas Service," and the Seventeenth Report of the Gas Investigation Committee, the responsibility for the work in which has largely fallen upon Mr. James W. Wood, the Research Chemist. These communications will receive separate attention in an early issue.

Next Year's Meeting at Cardiff.

Mr. H. D. Madden, M.Inst.C.E., is the new President of the Institution. Through him, the Chairman and Directors of the Cardiff Gas Company have extended a hearty invitation to the members to hold their meeting next year in the "Metropolis" of Wales. We know the Company to be in the front rank of progressive undertakings; we know, too, of the enthusiasm of the Board for all organized effort—technical and commercial—in the industry. There will be a warm welcome for the members of the Institution in Cardiff next year.

Coal Output.

In the week ended May 28, the total coal production was 5,071,000 tons; the number of wage earners employed being 1,025,700. In the previous week (ended May 21), the production was 5,052,200 tons; the number of wage earners being 1,026,700. The quantity of coal raised during the week ended June 4 was 5,102,900 tons; the number of workers being 1,022,500.

Steaming in Continuous Verticals.

In his paper at the meeting of the Institution of Gas Engineers, Mr. Thomas Carmichael called attention to a matter which should receive the attention of contractors for continuous vertical retorts. He suggests that an endeavour should be made to utilize a larger proportion of the steam introduced into the retorts. This should prove a useful field for investigation, not only by research workers, but by the plant manufacturers. The steam efficiency in works practice can only be calculated approximately from the gas analysis; but Mr. Carmichael points out that it is of the order of 30 p.ct. He regards it as somewhat surprising that, when steam is admitted at the base of the retort at the rate of (say) 100 lbs. per hour, 70 p.ct. should escape unchanged at the top. Where waste-heat boilers are in use, the cost of this steam is perhaps negligible. But the matter is of considerable importance from the point of view of condensation and ammonia recovery. It will be seen that the point received a good deal of comment in the discussion. Some speakers suggested that a better decomposition would be effected if a higher temperature were used; but there was other evidence that, with even higher temperatures, the effect of condensed steam upon the liquor adversely affected the sulphate process.

French Coal Embargo.

Further to this subject, the strong feeling which has been aroused in France among shippers and importers of coal, and the industries which prefer British coal, as well as among British coal owners and shippers, shows no abatement. Last week the question was referred to on several occasions in the House of Commons. Early in the week, it was mentioned that His Majesty's Ambassador in Paris had made strong representations against the French decree. On Wednesday, it was stated that, though the decree had been in force from the 10th inst., licences were being issued; and those granted up to June 14 for deliveries of coal from the United Kingdom during June, July, and August, amounted to 2,800,000 tons. The total comprises coal for all purposes, including railways and public works. The Government are watching the position closely; and there is promise that, should it appear that the operation of the decree will seriously prejudice the British export trade, further representations will be made to the French Government.

Non-Political Miners' Union.

It is just possible that the Executive of the Miners' Federation will find that their antagonism to Mr. Frank Hodges, which led to his resignation of the secretaryship of the International Miners' Federation, has opened up a position in regard to him which they could not have contemplated, and would rather not have seen. It is reported that a resolution has been carried by the Notts. and District Industrial Miners' Union, and the Executives of the South Wales Industrial Union and the Durham Non-Political Union, which invites Mr. Frank Hodges to undertake the leadership of the Non-Political Miners' Unions in this country. If this occurs, those Unions will obtain very strong support throughout the country; and the Miners' Federation will have cause for further lamenting the course of events. In at least five counties, the non-political movement among the miners has grown considerably during the past six months; and everything points to the various non-political bodies becoming organized into one Federation. It is reported that the Miners' Federation are in very low water with scarcely half the miners in financial membership. This is the secret of the frightful prognostications of Mr. Cook.

Prodigality in Local Administration.

A second reading was last Wednesday accorded to the Audit (Local Authorities) Bill by 229 votes to 94. It will be remembered that this measure has been launched by the Government for the purpose of protecting ratepayers against prodigal local administration. From the Labour-Socialist party the Bill has been denounced as a deliberate attempt to smash the party, and even local government itself. It is illogical of the party to assume that it and local government are one and the same. The absurdity of the contention is also shown by the fact that the auditors are concerned only with the surcharge of illegal items; and it is futile to submit that local bodies should be in a position to place themselves above the law. It is believed by the Government that, in the case of surcharges, five years' disqualification from membership of local authorities, and recovery by civil process, are likely to be far more effective than liability to a term of imprisonment. This is not a political matter; it is a question of the defence of the ratepayers.

Peace in Industry.

An important announcement was made by Sir A. Steel-Maitland in the course of the discussion of the Trade Disputes Bill in the House of Commons last Tuesday. It was to the effect that the Government have decided to appoint a Committee representative of all the parties concerned to conduct a thorough investigation into the whole machinery of industrial conciliation. No definite plan has yet been decided upon, as the Minister of Labour desires, before committing himself, to consult with the Labour party as representing the trade unions, and the employers and their organizations. The desire is to make the Committee workable and suitable to the practical needs of industry. It is expected that all the existing forms of conciliation machinery will fall within the scope of the inquiry—such as Conciliation Boards, Whitley Councils, and Industrial Courts—and there will be examination into their success or failure for the purpose of determining whether or not development is possible or whether entirely new machinery is desirable. So far, the Labour-Socialist party have shown no particular desire to encourage the Government in this new effort; but probably, after due reflection, they will see that it will be better to participate in the inquiry than to stand aloof.

FORTHCOMING ENGAGEMENTS.

June 24.—WAVERLEY ASSOCIATION OF GAS MANAGERS.—Annual meeting in Edinburgh.

June 25.—SCOTTISH JUNIOR GAS ASSOCIATION (EASTERN DISTRICT).—Annual meeting and visit. Inspection of the Dunfermline Gas-Works.

June 28.—SOUTHERN ASSOCIATION OF GAS ENGINEERS AND MANAGERS (EASTERN DISTRICT).—Meeting at 28, Grosvenor Gardens, S.W. 1, at 2.45.

July 12.—NATIONAL GAS COUNCIL.—Annual meeting at the Hotel Cecil, at 3.15.

July 12.—FEDERATION OF GAS EMPLOYERS.

Sept. 7-9.—NORTH BRITISH ASSOCIATION OF GAS MANAGERS.—Annual general meeting in Dumfries.

Sept. 23.—SOUTHERN ASSOCIATION OF GAS ENGINEERS AND MANAGERS.—Visit to the Torquay Works of the Torquay and Paignton Gas Company.

Oct. 3-5.—BRITISH COMMERCIAL GAS ASSOCIATION.—Sixteenth annual general meeting and conference at Southampton.

INSTITUTION OF GAS ENGINEERS.

July 11.—Emergency Committee.
Finance Committee.

July 12.—Gas Education Committee.

PERSONAL.

CHANGES AT CROYDON.

Hearty congratulations to Mr. W. J. SANDEMAN, Distributing Engineer and Sales Manager of the Croydon Gas Company, on his appointment by the Board as General Manager. Mr. Sandeman's services to the Company are too well known to need any reference here; his elevation is a recognition of those services, and the best possible expression of the confidence of the Chairman and Directors.

In the "JOURNAL" for May 18, we announced the approaching retirement of Mr. Archibald Caddick, the Engineer of the Company. We congratulate Mr. WALTER GROGONO on his appointment as Mr. Caddick's successor. Mr. Grogono has been in the service of the Gas Light and Coke Company for some years, and is now at their Fulham Station. In his new sphere, he will have good scope for his talents; and we wish him very cordially the utmost success.

Both appointments date from July 1.

Mr. EDWARD CROWTHER, of Stoke-on-Trent, who takes up duty on July 18 as Deputy Gas Engineer at Bradford, is of a Huddersfield family—son of the present Engineer and Manager to the Wallasey Corporation Gas and Water Department. He was educated at Wallasey Grammar School and Liverpool University, and graduated Master of Engineering after being engaged in research work in internal combustion engines and liquid and gaseous fuels. He became Assistant Engineer at Wallasey after a year in the Royal Engineers.

The Stratford-on-Avon Town Council have voted an honorarium of £50 to the Gas Manager (Mr. F. Shewring) for additional services rendered by him at the works in connection with the purification of gas.

At the last meeting of the Devizes Town Council, the Gas and Water Committee recommended that the salary of the Engineer and Manager of the Gas and Water Works (Mr. W. J. Rendell Baker) be increased £50 per annum. There was no dissent.

SOME INDUSTRIAL APPLICATIONS OF HIGH-PRESSURE REACTIONS.

The seventh lecture on "High-Pressure Gas Research" was given by Prof. W. A. Bone, F.R.S., on Friday last at the Imperial College of Science and Technology. Dealing with some of the industrial applications of high-pressure reactions, Prof. Bone described in some detail the methods of obtaining oxides of nitrogen and nitric acid by making use of the energy developed in gaseous explosions. The formation of oxides of nitrogen under such conditions was first observed by Cavendish and later by Bunsen, and a method, based on these observations, for working on an industrial scale has recently been put into operation in Germany by Hausser. The influence of pressure upon the yield of oxides of nitrogen formed during an explosion of carbonic oxide with excess of air was first discovered by Bone, Newitt, and Townend during the course of an investigation upon some of the problems concerned with the combustion of carbonic oxide in closed vessels; and it has been shown that quantities of oxides far in excess of those required by a purely thermal equilibrium (at the temperatures attained in the explosions) are produced.

Another interesting application of high pressures is due to Dr. Bergius, who, by hydrogenating coal under pressure, has been able to increase considerably the yields of oil. The plant for operating the process comprises a unit for generating hydrogen, compressors, hydraulic pumps, high-pressure pipelines, and reaction vessels. It is an excellent example of the methods of handling materials at high pressures and temperatures. A full description of the semi-scale and large-scale plants installed at Rhineau was given, and was illustrated by slides kindly lent by Dr. Bergius for the occasion. The working pressure of the semi-scale plant is some 200 atmospheres, and the necessity for pumping very viscous liquids at this pressure, and of separating liquids from gases at the discharge end of the plant, have led to some interesting developments in chemical engineering.

The last lecture of the series will be given in the Department of Chemical Technology on Friday, June 24, and will deal with other high-pressure reactions of technical importance.

UNION SYNDICALE DE L'INDUSTRIE DU GAZ EN FRANCE.

Mr. John Terrace, the Junior Vice-President of the Institution of Gas Engineers, writing from Lille, says: Particular interest attaches to the 50th Congress of the Industrie du Gaz, held at Lille, by reason of the formation of a new body which appears from inquiry to be somewhat similar to our National Gas Council. We are all familiar with the title of the Société Technique de l'Industrie du Gaz en France, which for reasons of company law now becomes the "Association Technique," and will be associated with the Union Syndicale much the same as the Institution of Gas Engineers is with the National Gas Council.

The membership of the Union Syndicale will be the various undertakings, while that of the Association Technique will be, as heretofore, the Engineers themselves. The President of the Association is Vice-President of the Union Syndicale. The new body will interest itself largely in matters of State regulation of the industry and negotiations with Labour representatives, though it is not yet definitely decided whether a committee corresponding to our Federation of Employers will be formed. There is not yet in existence a body corresponding to our British Commercial Gas Association, though such would appear likely to grow out of the present efforts being made in publicity work; but other branches are the Coke Committee and the Heating Bureau.

Clearly our French colleagues have been impressed by the advantages resulting from having a representative body to deal with other than technical matters; and we wish them every success in the development of their efforts. The first President of the Union Syndicale is M. R. Ellissen, already well known to English engineers. M. Baril is the first President of the Association Technique.

GAS UNDERTAKINGS AND LOW-TEMPERATURE CARBONIZATION.

(FROM A CORRESPONDENT.)

It is very interesting to note the activity in the two largest Gas Companies in this country with reference to low-temperature carbonization. The Gas Light and Coke Company, as is well known, have made arrangements with the Fuel Research Board to erect a type of retort which has been evolved at Greenwich, and to test the Fuel Research Board's ideas on a commercial scale. It is also understood that they have obtained from the Government, under the Trade Facilities Acts, the sum of £100,000 for the purpose.

The South Metropolitan Gas Company are evidently also considering seriously steps in the same direction. When the writer was at Essen recently, he was informed that a representative from the South Metropolitan Gas Company had visited the Stinnes low-temperature carbonizing plant the previous day; and that Dr. Carpenter, the President of the Company, was also expected. The writer believes that a low-temperature plant will be erected at the works of the South Metropolitan Gas Company, in order to produce not only a domestic free-burning smokeless fuel, but a gas of high calorific value for town-gas carburetting purposes. This information is very interesting, in view of the attitude which has been taken up by gas undertakings until latterly. Furthermore it gives an indication that gas undertakings are getting tired of having to pay the extremely high prices at present prevailing for imported gas oils, and are therefore looking to low-temperature carbonization or distillation of coal to produce a rich gas which can be used for carburetting. Whether or not the process will be finally adopted by the South Metropolitan Company, remains to be seen. But the point is that apparently the ice has now been broken; and high-temperature people are beginning to realize that, by working in conjunction with low-temperature processes, mutual advantages will follow.

Regarding the information given in the first paragraph of the above, it is well known from statements made by Sir David Milne-Watson, and in the House of Commons, that, working in conjunction with the Government and the Fuel Research Department, the Gas Light and Coke Company are going to "try-out" a process of low-temperature carbonization at their Richmond Station. Publication has been given to the further information that a Company, Fuel Utilization, Ltd., has been specially formed for the purpose of this research and experimental work, and also that, under the Trade Facilities Act, the Government will contribute £100,000. It is understood that the nation's interest in the event of the experiments proving successful is safeguarded. The work of erecting the plant is to proceed at once (from the designs of the Fuel Research Department) for the production of smokeless fuel, motor spirit, and other fuels on the commercial scale. It is hoped to have it in operation about the end of the year.

It is also stated that, to provide working data, it is intended to operate the plant intensively for about three years, unless, of course, complete success is achieved in a shorter period. At the end of the three years, the results will be reviewed, and the works extended or closed-down as circumstances dictate.

"American Gas Journal."—A communication received last week from the Editor, Mr. H. M. Riley, informs us that the "American Gas Journal," which has been published continuously as a weekly since 1859, is in future to be issued monthly.

INSTITUTION OF GAS ENGINEERS.

ANNUAL MEETING,

AT THE

INSTITUTION OF ELECTRICAL ENGINEERS, VICTORIA EMBANKMENT

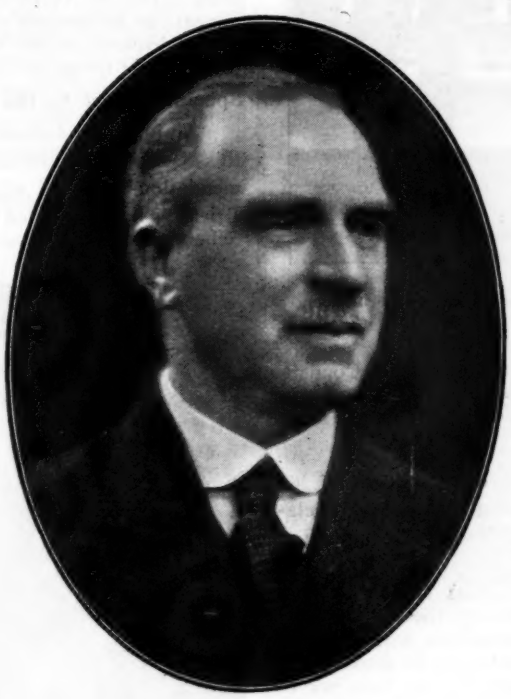
JUNE 14, 15, and 16.

President: JOHN WILKINSON, Esq., O.B.E.

REVIEW OF THE PROCEEDINGS.

[A Verbatim Report is given on later pages.]

BOTH outside and inside the home of the Institution of Electrical Engineers on the Victoria Embankment (which, as on certain previous occasions, generously afforded accommodation to the Institution of Gas Engineers), great geniality prevailed on the opening day of the annual meeting last week. The weather was kindly disposed; and there were no clouds in the industrial sky, as there were at the time when the annual meeting should have been held last year, and the full dreariness of which was being felt, in the shape of trial and difficulty, at the time of the postponed meeting in the early autumn. The scenes outside the building and in the commodious hall were much the same as they have ever been during the past half-a-century. Friends from all quarters of England, Wales, Scotland, and Ireland met again, and greetings were broadcast.



JOHN WILKINSON, O.B.E.

It was highly significant that when their popular President, Mr. John W. Wilkinson, O.B.E., of Nottingham, took the chair (which commenced the gaining by him of fresh laurels among his professional colleagues), the hall was well filled—in fact, during the delivery of the Presidential Address, and for most part of the morning sitting, there were no spare seats, which showed that even the allurements of Ascot were failing to draw members from the conference which had brought them together. With the President as he took the chair was Sir Albert Ball, who is one of those gas administrators who has a happy place among professional gas men through his spirited chairmanship of the Nottingham Corporation Gas Committee, and his consistent championship of all movement for the advance of the gas industry. There were also Mr. H. D. Madden, who is now the President of the Institution, Mr. J. W. McLusky, who has become Senior Vice-President, and Mr. John Terrace, who is the successor of our last-named friend in the Junior Vice-Presidency. There were present practically all the members of the Council, and with them, fulfilling their functions with their well-known assiduity, were the Hon. Secretary (Mr. W. E. Price) and the Secretary (Mr. Walter T. Dunn). The stage was complete for what promised to be a fruitful meeting, and the promise has been abundantly fulfilled. When the President rose and bade the members a cheery welcome, he was greeted with enthusiastic applause.

Award of Honours.

There was a little general and other business to be transacted before reaching the Presidential Address. Chief among this was the presentation to Mr. C. H. Rutter, M.Inst.C.E., of the H. E. Jones "London" Gold Medal for his paper of last year on "The Development and Reconstruction of the Portslade (Brighton) Gas-Works." The President spoke true words when he said that Mr. Rutter prepared his paper with no thought of reward; but he was sure that he felt considerable pride at the fact that his fellow-members had seen fit to honour him by awarding him this coveted medal. The honour was suitably acknowledged by Mr. Rutter. The next pleasing duty of the President was to present the diplomas in gas engineering which had been awarded as the result of the last examination under the Institution Education Scheme. A first-class diploma was gained by Mr. Henry Preston Lupton, B.Sc., Liverpool, and second-class diplomas by Mr. J. W. Pallister, A.M.Inst.C.E., of Middlesbrough, and Mr. Edward Morgan Edwards, of the Holyhead and North Wales Gas and Water Corporation. There was hearty endorsement of the good wishes expressed by the President that professional lives so well started would continue to advance with credit to the recipients of the diploma, and with advantage to the industry which they have chosen to serve.

Honorary Members—Mr. John F. Simmance.

Succeeding the election as honorary members of the Presidents of kindred Associations in other lands, there came the resolution which placed on the Roll of Honour of the Institution the name of Mr. John Frederick Simmance. This is a case of a scientific worker in the gas industry, who has within it no actual official or professional status, receiving recognition of the incomparable work he has rendered to it by the combination of scientific talent and constructive ingenuity. The President in apt words sketched the work of Mr. Simmance, which has made a large contribution to the means of controlling

gas operations, and has brought us advance in manufacturing economies and efficiencies, and at the same time has aided, as necessary, in the defensive. There was a round of cheering as the President moved the resolution which brought Mr. Simmance into the fold of the Institution through the class of honorary members. In well-chosen

The Recipients of the Institution Diploma.—Messrs. H. P. Lupton, J. W. Pallister, and E. M. Edwards.

words, Mr. Simmance thanked the President, Council, and Members for the distinguished mark of approval which they had given to a long life's industry.

His Chairman's Testimony.

Just preceding the delivery by the President of his address, Sir Albert Ball interposed a few remarks relative to his association with Mr. Wilkinson. He had many nice things to say concerning him; and when a Chairman can speak of the chief official of a Gas Department as did Sir Albert, it is evident that, through their work, they have become great and constant comrades, with a single eye to their respective functions combining to produce the best possible in the interests of the citizens they serve. Sir Albert took the opportunity of formally inviting the Institution to visit Nottingham on the Friday, and he assured the members, in his delightfully felicitous way, that in the city there would be a generous welcome, and given fine weather a day of great interest and enjoyment.

The Presidential Address.

Regarding the Presidential Address, an indication of its contents, together with comment, is given in our editorial columns. Therefore, in this review, it is unnecessary to attempt to present an outline of the deliverance. Suffice it to say that its practical material and structure maintained the perfect interest of the members from the opening sentence to the final words, and the manner of delivery accentuated point and emphasized the convictions of the author. When Mr. Doig Gibb, in proposing a vote of thanks to the President for his address, stated that it was from an enlightened and far-seeing mind, he was merely expressing what the whole of the members felt. His motion was seconded by Mr. Thomas Glover; and the meeting gave to it an endorsement which showed the President that, with whatever trepidation he had commenced the writing of the address, he had succeeded in giving satisfaction to others which perhaps is, in such a case, of greater importance than giving satisfaction to oneself.

A formal acceptance of the annual report and accounts brought us directly to the

Report of the Education Advisory Committee.

The Annual Report of the Advisory Committee opened with the good news of a 30 p.ct. increase in candidates for examination, following a 50 p.ct. increase in 1926. This, however, was momentarily clouded by the information that the number of gas supply students has fallen far short of the industry's requirements, and that only 14 technical institutions out of 30 with approved schemes have sent up candidates. The remainder of the report, however—and indeed the whole proceedings connected therewith—dispelled this shadow, and left the impression that matters concerning technical education in the industry will now enjoy uninterrupted advancement. The inauguration of a Teachers' Training Course in July, regarding which the "JOURNAL" has already given full particulars, is one example of the united effort that has been made.

By far the most important event in the year has been the conference on March 9 between the Advisory Committee, the Examiners, the Committees for Scotland and Wales, and representatives of the Junior Associations. This led to further discussions; and the outcome appears to be eminently satisfactory, and to hold the key to the dispersal of the difficulties which have been known to exist. It takes the form of a

Special Report to the Council.

An immense amount of work must have been put into this special report, for each of the observations and recommendations tells of sifted evidence and fine judgment. Briefly it may be stated that weak points in the Education Scheme are imputed to (1) the apathy of certain under-

F. W. GOODENOUGH, C.B.E.

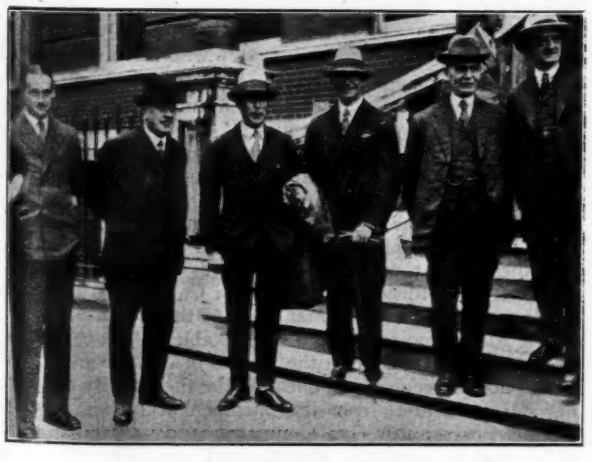
takings; (2) want of knowledge on the part of would-be students of the scheme and its working; (3) the scattered nature of the industry; (4) the existence of provisions which might be modified. In dealing with these disabilities, the Committee have held fast to the idea that, though the letter of the law may be modified, the spirit of

the scheme is "satisfactory education," which must be inviolate. There must be no departure, therefore, from the fundamental principle of a broader base for the scheme than the mere capacity to answer questions; wherein is discovered the reason why a bare correspondence course is barred.

Dealing now with the proposals—again in brief—it is intended in the first place, now that the report has been adopted, to set-up District Education Committees, on which the Senior and Junior District Associations will be represented, together with a member of the local education authority. It is suggested that technical schools which have hitherto been unable owing to a shortage of pupils to inaugurate classes, would be willing to do so if the

On the Steps of the Meeting Place.

necessary numbers were forthcoming through the co-operation of neighbouring gas undertakings. In areas where no technical school exists, then the Committee may dispose that the required auxiliary subjects may be taken at a secondary school. Finally, with the view of clearing obstacles from the path of older men who may hold established posts in the industry, but desire to improve their status, the Committee reserve the right (*a*) to dispense with the Ordinary Certificate if they can be satisfied that a student has reached the standard in earlier years of study; (*b*) to accept for examination, up to June 30, 1930, students who can prove a certain standard of attainment in ancillary subjects; (*c*) to excuse, in certain cases, attendance for ancillary subjects at a Technical School; in



A Group from Brighton.

certain exceptional cases to exempt candidates from possession of the Higher Certificate or from evidence of general education.

Heavy Support Assured.

Mr. Goodenough having proposed, and Mr. Samuel Tagg having seconded, the adoption of the report, the representative of the Junior Associations, Mr. James Bridge, of Elland, rose to support it, and found himself in a position to promise the whole-hearted approval and co-operation of the "Juniors." Mr. Madden followed, to dispel in charming manner the illusion of our childhood that all examiners are ogres, and to leave the certainty that they are the friends of the student—determined, nevertheless, to administer the spirit, without bureaucratic observance, of the law. Mr. Clark Jackson, of Neath, exposed a difficulty in announcing that authorities coming within the Ministry of Health Audit are debarred from offering any assistance, financial or otherwise, to would-be students; and as opinions differed in this regard, Mr. Goodenough promised that the matter should be investigated, and if necessary taken-up in high places. Mr. Bernard Kelham (late of Perth, Australia) showed that the industry even in that far country takes a live interest in the Education Scheme.

Altogether a most satisfactory session of the meeting.

From Abroad.

The members were delighted to see present representatives of the Société du Gaz de Paris, in the persons of MM. Rançon, Simor Saint-Just, Reclus, and Joyeux. Of our own countrymen there were Mr. Bernard Kelham, an Associate Member of the Institution, and late of the Gas-Works, Perth, Australia; and Mr. C. H. Carder, a Member, who is home from Rio de Janeiro. All were heartily welcomed.

Combustion Products from Gas Appliances.

The Fifteenth Report of the Gas Investigation Committee dealt with the iodine pentoxide method for the

Before the First Session.

determination of carbon dioxide, and with tests on gas-fires. During the past year Mr. J. W. Wood and Mr. C. B. Howarth have further investigated this method of testing, and have examined the products of combustion from two gas-fires—one a typical modern nine-radiant duplex fire taking a normal gas consumption of 38·3 c.ft. per hour of 470 B.Th.U. gas at 1·6 in. water gauge; the other a ten-radiant fire (date 1911) having a normal consumption of 42·6 c.ft. at 2·4 in. water gauge—with a view to determining some of the factors affecting carbon monoxide formation. The Seventeenth Report is an account of this work. Systematic tests at different gas consumptions, and with different degrees of aeration were made at rates up to 30 p.ct. in excess of the rated capacities of the fires. The results are stated as the parts of carbon monoxide produced per 10,000 parts of gas burned, which renders them independent of the ventilation.

With the modern fire, at half the normal rate, and with normal aeration of the flames, the production of carbon monoxide was 15 parts per 10,000 of gas supplied to the fire, rising gradually to 30 parts at the normal rate. Above this, the carbon monoxide production rose very rapidly to 200 parts—2 p.ct. of the gas burned. The hourly production of carbon monoxide at the normal gas rate was 0·12 c.ft. With a higher degree of aeration, the

production of carbon monoxide was diminished, being 16 parts per 10,000 parts of gas burned at the normal rate. The highest production was less than 50 parts with a 25 p.ct. overload.

Effect of Increased Aeration.

At half the normal gas rate, and with low aeration of the flames, the carbon monoxide production of the 1911 fire was practically the same as for the modern fire, but it increased rapidly as the gas rate increased, until 235 parts per 10,000 parts of gas burned was reached at the normal gas consumption. At this rate the production was 0·98 c.ft. per hour. With this fire, increased primary aeration resulted in the reduction of the maximum carbon monoxide production to about half the value given in the low aeration tests.

As in the Fifteenth Report, it is stated in the Seventeenth that, though the amount of carbon monoxide per unit of gas burned is small, the total quantity when the gas consumption is taken into account may not be negligible. There may be sufficient to justify the continuation of present good practice—that all fires should communicate with efficient flues. A comparison of the results given in the Seventeenth Report with others obtained in work carried out on coal and coke fires by Margaret Bligh and H. J. Hodsman at Leeds University shows that the thermal wastage from carbon monoxide production is much higher with a solid fuel fire than with a properly adjusted gas fire.

Design of Radiants.

The report emphasizes that there is still a field for investigation in devising a radiant that will yield the maximum radiant efficiency with the minimum carbon monoxide production. The radiants fitted to the pre-war gas fire were straight fireclay tubes 8½ in. long perforated with diagonal slots at the back and covered internally with studs of fireclay. Cross-pieces were in some of the experiments provided to fill the gap between the top of the radiants and the firebrick back. The radiants of the modern fire were bent over near the top, to obviate the need for separate top blocks. These radiants were 1¼ in. from back to front near the base, compared with 1 in. for the older radiants. When the latter were fitted to the modern fire, the CO production was the lowest observed in any of the tests, which refutes any suggestion that higher CO figures were obtained with the pre-war fire because the radiants were of smaller bore. The CO production was high when the newer radiants were fitted to the older fire—amounting to practically 500 parts of carbon monoxide per 10,000 of gas burned (*i.e.*, 5 p.ct. of the gas) at 4·5 c.ft. per radiant per hour. The tests indicate that visual observation of the condition of a fire in operation is not entirely trustworthy when carbon monoxide formation is in question. They also suggest that it is unwise to employ radiants in a fire which are not expressly designed for that fire. Tests were also carried out with both types of radiant in the modern fire. The older radiants were superior in showing a lower carbon monoxide production. Though the new radiants lead to a higher carbon monoxide production than the older ones, the difference between the two fires is so great that the combination of the modern gas fire and the new radiants gives a net result which is a considerable improvement on any carbon monoxide figure obtained with the older fire. The conclusion is drawn that cross-pieces are undesirable; and the view is put forward that probably the new radiants are too large and do not become fully heated, so that the flames are chilled and carbon monoxide appears in the flue gases.

Flueless Gas Heaters.

The importance to the gas industry of studying the effect of immersing a solid in a flame—such as a radiant in a gas fire flame—was stressed by Prof. Cobb in his introduction to the report. Any solid which breaks up the structure of a flame, and prevents it assuming its normal shape, affects the production of carbon monoxide. Another point emphasized by Prof. Cobb was that a gas fire is less liable to produce carbon monoxide than the solid fuel fire, either coal or coke—a fact to which Mr. Ferguson Bell, of Derby, referred in the subsequent discussion, which was highly interesting. Mr. Bell also congratulated the makers of gas fires on the enormous advance they have made during the last few years. Practically all the speakers suggested that lip-service to the Research Committee should be backed-up by financial support. Mr. W. J. A. Butterfield expressed the hope that the Committee would, by further investigation, be able to indicate under what conditions gas heating appliances may be used safely without flues, for there are rooms which it is difficult to heat in any other way than by the "stuffy electric radiator." He suggested that the results of the report were not such that one need fear harm if a gas fire is used properly in a reasonably ventilated room, provided the products of combustion are led above breathing level. He is of opinion that flueless gas appliances are, indeed, very useful in promoting ventilation—much more so than an appliance, such as the electric radiator, which gives no products of combustion.

Study the Reports.

Mr. J. H. Brearley, of Southport, trusts that no members of the Institution feel impatient with the speed of work of the Research Committees. If impatience does exist, it must be due to lack of appreciation of the thoroughness of the work and the significance of the findings. That hollow vessels create the greatest din is as true to-day as it was in the time of Nebuchadnezzar.

Mr. C. F. Botley, of Hastings, referred to Mr. Wood's statement that the amount of carbon monoxide in the resultant products of combustion is independent of the quantity of this compound present in the original gas. Very rightly he regards this as an important pronouncement, and hopes that sight will not be lost of it.

Election of Officers.

At this stage in the proceedings the President announced the result of the Scrutineers' examination of the voting papers, which showed that Mr. H. D. Madden, of Cardiff, has been elected President for the ensuing year; Mr. John Terrace, of the South Suburban Gas Company, Junior Vice-President; Mr. W. E. Price, Hon. Secretary; and Messrs. T. Carmichael, R. E. Gibson, R. Robertson, and W. J. Smith, Members of Council. Mr. A. E. Broadberry and Messrs. Wood, Drew, & Co. were appointed Auditors.

Cheapening the Therm.

Mr. Thomas Carmichael, Engineer of the Portsmouth Gas Company, next read a paper on "Modern Carbonizing Economics." There must be very few members of the engineering side of the gas industry who have not studied the excellent paper which Mr. Carmichael presented to the Southern Association of Gas Engineers and Managers in November, 1922 ("JOURNAL," Nov. 29, 1922)—the results contained in which have been quoted constantly since that date. In that paper, the author gave comparative costs of production of gas from various plants; but in some cases the figures were estimated. These have since been ascertained on a basis of actual production; and the present contribution extends and brings up to date the costs formerly given. Mr. Carmichael's account of his recent work is of great value to the industry.

The author points to the remarkable influence exerted by the size of the coal on the results of carbonization, and shows how screening can cheapen the therm. By eliminating dust and fines from the unscreened coal as received by the Portsmouth Gas Company, and carbonizing the large coal in verticals, the thermal yield per ton is increased 10 p.ct., and the output of the plant by no less than 20 p.ct. Moreover, there is less sticking of the charge. The fines resulting from the screening are carbonized in the horizontal plant; and while the make per ton falls slightly—by 1·4 therms—the throughput remains practically the same. Many works possess both verticals and horizontals; and to the managements of these undertakings Mr. Carmichael's experience of screening will prove of much benefit. Screening of the coal, of course, renders the vertical coke more saleable for domestic pur-

poses. At Portsmouth, they sell the whole of the output of coke from the vertical retorts, and manufacture water gas as far as possible from horizontal coke only.

Cost of Coal the Important Factor.

It is shown clearly by the author that the cost of the therm is largely a question of the cost of coal into store. Durham coal gives the cheapest therm when carbonized in the newest type of vertical plant. The next process in order of cost is the straight carbonization of Durham coal in unsteamed verticals and in horizontals; followed by blue water gas; and finally carburetted water gas. Regarding the cost of water gas, however, Mr. Carmichael remarks that "the value set upon the coke used in water-gas manufacture is really an artificial figure. . . . A reduction in the manufacture of water gas would result in the lowering of the market price of coke, and consequent cheapening of the water-gas therm." The cheaper coke would, of course, make the coal gas therm dearer "Thermal efficiency alone," states the author, "is not a sufficient index to the gas engineer of the relative values of particular plant or processes."

It is suggested that an endeavour should be made to render the steaming process more efficient—a subject

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which could well form the basis of research. When steam is admitted at the base of a vertical retort at the rate of (say) 100 lbs. per hour, 70 p.ct. of it escapes unchanged. This may be unimportant as regards the cost of its production where waste-heat boilers are in use; but it is certainly important from the point of view of condensation and ammonia recovery.

Maintenance and Capital Costs.

At one time many were of opinion that the maintenance costs of vertical retorts would be excessive. Experience shows, however, that "with well designed and constructed settings, properly worked and supervised, the costs are extremely reasonable." Mr. Carmichael gives a figure of 0·11d. per therm as the cost of maintaining a fireclay setting for twelve years, leaving at the end of this period a practically new plant. The estimated figure for a silica setting is 0·12d. per therm on the same basis. For horizontals capable of carbonizing 30 cwt. per retort per diem, the maintenance cost would be 0·14d. per therm. The corresponding figures for blue and carburetted water gas are 0·05d. and 0·03d. per therm respectively.

With regard to capital costs, the author puts forward the following figures: For modern verticals, £3625 per 1000 therms per day; for modern horizontals, £3715; for blue water-gas plant, £4290; and for plant producing C.W.G. of a calorific value of 465 B.Th.U. per c.ft., £2796. The final comparative over-all therm costs, including maintenance and capital charges, show that vertical gas and horizontal gas can be produced at approximately the same cost, but that water gas and carburetted water gas—particularly the latter—are much more expensive.

In concluding the paper, Mr. Carmichael says that the most desirable carbonizing plant, from the economic standpoint, is the one best equipped to meet the variations in the commercial values of coal and residual products. "The experience of the past few years has proved that cheap coal and low receipts for residuals are not usually of such long duration as to encourage engineers to bind themselves definitely to one form of carbonizing." Flexibility should be provided, and the capacity and condition of the distribution plant should be considered. In 1921, by the way, Portsmouth declared a C.V. of 450 B.Th.U.; and, "in the light of subsequent experience and experiments," states the author, "no reason has been found for deviating from this figure."

Swelling Prevents Free Travel of the Charge.

The obvious enthusiasm with which the members listened to the paper, and the lengthy discussion which it evoked, must have been very gratifying to Mr. Carmichael. Mr. Frank Prentice, of Ipswich, who, after congratulatory remarks from the President, was the first to join in the discussion, mentioned that it was thirteen years since he first installed verticals at Ipswich, since which time he had travelled on the same road as Mr. Carmichael. Mr. Prentice quickly discovered that unscreened Durham coal created difficulties when attempts were made to carbonize it in verticals; and he adopted a method of taking out the fines for carbonization in horizontals. His method is the simple one of having raised ploughs on the steel conveyors. He threw out the suggestion that the trouble caused by carbonizing smalls in verticals is not so much a question of the grade of coal as of its swelling properties. When large coal is charged into a retort, the interstices between the lumps of coal are sufficient to take-up the swelling of the mass—a compensating factor which does not obtain when the retort is charged with small coal. His experience during the recent coal strike amply demonstrated this. The coal received was composed largely of fines; but, because it was a non-swelling coal, it passed through the retorts without any difficulty. He therefore put forward the view that if to unscreened Durham coal 3 or 4 p.ct. of a non-swelling coal is added, difficulties will be overcome. Mr. Prentice concluded his remarks by mentioning that a Durham colliery had adopted the practice of taking out the dust from the coal they supplied to him. The result is amazing; and the coal can be carbonized in the latest W.D. verticals without the slightest trouble.

Support of Horizontals.

Mr. W. H. Warren, of the Gas Light and Coke Company, expressed himself as startled at the conclusions which Mr. Carmichael had drawn. The author, he observed, had compared the latest model of vertical plant with what was a comparatively old horizontal installation, and one which was economical with regard to neither its size nor its charging mechanism. These horizontals were called upon to make a gas of uneconomic quality; and yet the commercial efficiency was almost equal to that of the vertical plant, and the thermal efficiency was superior. Moreover, the author had utilized his screenings in the horizontals, which naturally made the verticals appear in a more attractive light. There was another point, the author used the horizontal coke containing the bulk of the ash in his water gas plant, in this way penalizing its working. Mr. Carmichael admitted this, but he would not admit that the horizontal plant was out of date. Following his observation that the fuel for heating the horizontal setting was much greater than that needed for the verticals, and yet 11 cwt. of coke was made in each case, Mr. Warren retired from the lists. He received support,

however, from Mr. J. W. Whimster, of Bath, who produced figures to show that a modern horizontal setting could be operated more economically than a vertical plant.

Silica an Essential Refractory.

A machine-gun fire of questions was opened up by Mr. Valon Bennett, of Rochester, from which it emerged, among other things, that Mr. Carmichael is a staunch believer in silica. He thinks, indeed, that it is up to the larger undertakings to stand the cost of a material which will ultimately benefit the whole industry. Mr. P. S. Hoyte, of Plymouth, relieved the technical tension by remarking that though, as had been said by Oscar Wilde, three addresses always inspired confidence in tradespeople, it did not follow that three entirely different types of carbonizing plant would prove most economical, for the difficulty would arise of keeping them all at work together. The author's screening system implied that the coal received would fully supply the horizontals with smalls and the verticals with large coal. Mr. Hoyte then pointed to the difficulty of dissecting with any real accuracy the costs of producing coal gas and water gas when both types of plant are in use together. He thinks the task hopeless.

Comparison of Mr. Carmichael's work on grading with that carried out this year on the same subject at the Leeds University was made by Dr. A. Parker, who emphasized the beneficial effects of screening; and Mr. H. E. Copp, of Hull, suggested that, instead of the fines being sorted-out from the coal as received, the object of securing free travel of coal in a vertical retort might be achieved by mixing a proportion of breeze or screened coke with the coal. Blending is best, of course, but there is an economic limit. Among other points to which Mr. Copp drew attention was the comparatively small percentage of steam decomposed in the author's plant. Perhaps this was due to the temperature of working, and improvement might result if the latter was raised to 1400°. Mr. H. H. Gracie, of Edinburgh, however, explained that he works his verticals at 1400° to 1450°, but without any material improvement in the percentage of steam decomposed. The undecomposed steam leads to a very weak virgin liquor; and having regard to the increasing difficulties of marketing sulphate of ammonia, he thinks that the whole problem is one which might well be investigated by the Research Committee of the Institution.

Local Conditions the Deciding Factor.

Mr. W. M. Carr, of Stretford, pointed out that while the author had employed smalls in his horizontals, he had debited them with the cost-of-coal figure used for the verticals. This may be all right for undertakings distant from the coalfields, but it does not apply to those near them, who can buy smalls cheaper than large coal. Mr. Carmichael had made out a strong case for the vertical-horizontal combination at Portsmouth; but local conditions differing from those at Portsmouth might well alter the situation. A few remarks by Mr. H. Chamberlain, of Sheffield, who said it would have been interesting if the author had included a comparison of the impurities (particularly sulphur) and inerts in the horizontal gas and the vertical gas—a feature which Mr. Chamberlain considers of great importance—brought the discussion to a close; and Mr. Carmichael replied to the many questions which had been asked.

Modifying Methods to Achieve Results.

Take a few hundredweights of coal. It is black. We will make gas from it. How much? Who knows? Let us ram it into a retort, and wait and see. What about the coke? We have enough to do to keep-up the heats and to clean out stopped pipes, without worrying about this. Let us get on with our work.

Such was the old-time attitude of mind in which the gas manager approached his task. And who shall blame him, when consideration is given to the lack of encouragement he received? To-day the position is vastly different. Thanks to such work as that undertaken by the Gas Investigation Committee, the modern gas manager is able to modify his process to achieve a desired result. The old "roulette" methods have given way to logical systems. For several years the Research Sub-Committee of the Institution and the University of Leeds have been labouring hard to render the task of the gas engineer easier, and to enable him to meet competition with confidence. This work, which is characterized by a thoroughness respected not only in this country, but in Europe and America, has on occasion been subject to destructive criticism, which has not lightened the task. Criticism there must be; let it be constructive.

Last year, in their Sixteenth Report, the Sub-Committee presented their first findings in a systematic examination of the influence of various factors on carbonization. The factor studied was that of variation in the size of coal carbonized; and in 1926-27 the investigation has been continued with the same coal (Nottinghamshire) to obtain information on the influence of grading the coal in different sizes, the admixture of different sizes, the temperature of the retort, the addition of coke breeze to the coal, and the addition to the coal of calcium carbonate, iron oxide, and sodium carbonate. The results are given in the Eighteenth Report of the Committee.

Coal Size and Gas Yield.

Mr. T. Carmichael, in his paper, "Modern Carbonizing Economics," demonstrates the advantage of screening the coal as received, and carbonizing the large coal in verticals and the smalls in horizontals. In view of this, the results set out in the Eighteenth Report have added interest, for it is shown that the large grade of coal produces a lower yield of gas, when carbonized in horizontals, than do the smaller grades. Mixing the grades appears to alter the rate of gas evolution, but not the total quantity; and in all cases the latter was in excess of that produced from the large-grade coal alone. By a reduction in temperature of 60° C.—from 980° to 920°—the thermal value of the gas made was diminished by about 4 therms per ton of coal, though the tar yield was increased. From the work of blending the Nottinghamshire coal with coke breeze, the conclusion is drawn that, with this coal, the disadvantages more than counterbalance the advantages which result from simple mixing without briquetting.

The results of carbonizing mixtures of coal and calcium carbonate, iron oxide, or sodium carbonate (98 parts of coal with 2 parts by weight of the corresponding oxides of these substances) are most interesting. The addition of the sodium carbonate gave an increase of 24 p.ct. in gas volume, equivalent to an increase of 12 p.ct. on the thermal yield. The thermal value of the gas as a result of the addition of calcium carbonate represented an increase of 5 p.ct., and with iron oxide 2 p.ct. The yield of ammonia which resulted from the addition of calcium carbonate was 35 p.ct. more than with the coal alone.

At the end of the Eighteenth Report is an account of the work in progress with the object of determining the differences in the physical structures, reactivities towards steam and carbon dioxide, and ignition temperatures of the cokes made during the investigation. Lowering the temperature of carbonization by 60° C. caused an increase in the reactivity of the coke towards steam; and greater increases in reactivity resulted from the additions of calcium carbonate, iron oxide, and sodium carbonate in ascending order as named.

Lowering the Sulphur Content of Gas.

In introducing the Eighteenth Report, Prof. Cobb drew attention to its value in connection with the important problem of the production of solid smokeless fuel. Low-temperature carbonization had been put forward as one method, but possibly partial and rapid carbonization at high temperatures would prove more economical commercially. He then referred to the effects of adding lime to the charge, the benefits of which—enhanced ammonia yield and lower sulphur content in the gas—have been claimed since the time of Cooper. The addition of lime (and the same thing applies to iron oxide, though in less degree) certainly lowers the sulphur content of the gas, though it increases the sulphur content of the coke. Regarding the latter, however, the remarkable fact emerges that when the coke is gasified in steam, very little of its sulphur is liberated. The importance of this was stressed

by Mr. C. F. Botley, of Hastings, who was the first speaker in the discussion which followed Dr. Parker's summary of the Committee's findings.

Mr. Thomas Glover, C.B.E., of Norwich, adopted the rôle of practical critic. He suggested that it is a pity the investigators confined themselves to one coal, and that some of the findings are commonplace. What, he asked, are the determinations of greatest significance? What is to be learned from the work? It is not sufficient to know that the addition of lime, iron oxide, &c., produces certain results; there ought to be information on how these effects are caused. He is not disposed to believe that the addition of sodium carbonate raises the ignition point of coke. Dr. Parker endeavoured to mollify Mr. Glover by explaining that the programme of the Gas Research Committee was an extensive one, and that, though they intend to investigate the properties of other coals when carbonized under similar conditions, they have not yet had time to complete more than a small section of the work. As to the ignition point of coke being raised by the addition of sodium carbonate, a great deal depends on the method of cooling the coke. If the latter is cooled rapidly in air, then the ignition temperature is high; if, on the other hand, the coke is cooled by water-quenching, the ignition temperature is lowered considerably. Moreover, if the air-cooled coke is allowed to weather, the effect on the ignition temperature, which is lowered, is remarkable.

The question of sulphur compounds in gas was discussed by Mr. F. G. Shaw, of Buxton, who regards the lower sulphur content of vertical retort gas as a strong point in favour of vertical carbonization. If, he suggested, it is possible, by the addition of a small quantity of some material, to reduce the sulphur compounds other than sulphuretted hydrogen in the gas, a great deal of trouble will be eliminated. At present Mr. Shaw is interesting himself in the removal of sulphur compounds by oil washing.

A Munificent Gift.

The Annual Meeting of the Benevolent Fund was taken first on Wednesday morning, when the President made a feeling reference to the loss the members had sustained by the death of Mr. S. Y. Shoubridge, whose efforts on behalf of the Benevolent Fund had been so whole-hearted. The wonderful response of the District Associations to the Committee's appeal was placed on record; and as regards individual subscriptions, the opinion was expressed that in the majority of cases non-subscribing is due to an oversight. The President kept for the full meeting of the Institution news of the munificent gift of £100 from their immediate Past-President, to be associated with the name of his father and that of the late Mrs. Botley, who is held in affectionate memory by many friends in the Institution. This open-handed generosity was acknowledged with enthusiasm.

Ovens as Gas-Works Plant.

After the newly elected Members had been introduced and accorded a welcome by the President, the meeting turned attention to Mr. Geoffrey Gill's paper on "Ovens as a Gas-Works Carbonizing Plant." In this, he purposely avoided comparisons between ovens and retorts, and ably carried out his intention of presenting facts. In view of the latter, the question requires answering why adoption of the "gas oven" is making such comparatively slow progress in this country. The author pointed out that this cannot be due to the coke from the ovens, which is suitable for every purpose but the open grate—always provided it is properly prepared and graded. As an example, his personal experience has proved that oven coke is admirable fuel for the domestic boiler, which he considers has altered the complexion of the coke market generally, and has made the outlook rosy for any undertaking that attends to the quality of its coke, whether from horizontals, verticals, or ovens.

The paper was sectionized according to the broad categories into which ovens may be divided; and the small horizontal oven was first dealt with. Such plant is easily adapted for the replacement of horizontal retorts; three ovens and one producer taking the place of nine retorts. The system is feasible for a works with an output of 300,000 c.ft. a day, or which might (say) use through horizontals with a charger-discharger. A typical installation was described and illustrated, in which four settings are installed; each oven having a charge of 400 lbs., which is carbonized in ten to twelve hours. The coke is quenched with a measured quantity of water; coal or coke is burned in the producers; and the labour required over a year works out to 1·25 man-hours per ton carbonized (which, it is stated, would apply to a plant of 50 p.ct. greater capacity). The makes of gas, coke, &c., given throughout the paper compare closely with retorting practice. Single units of the small horizontal oven may be installed; but the size of works that can employ them is limited by the fact that expensive mechanical plant is invariably necessary.

Flexibility.

The intermediate size of horizontal oven, which carbonizes 4 to 6 tons per 12 hours, may be regarded as a small edition of the full-size oven as far as construction and operation are concerned; and it is commonly called the "gas oven." Normal practice is for the oven walls, the heating flues, and the top portion of the regenerators to be built of 95 p.ct. silica; and many other interesting

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features were enumerated by the author. Coal pulverizing and blending plant is frequently provided in America. As regards labour cost, Mr. Gill cited the Fort Wayne Gas-Works, the capacity of which is 3 million c.ft. of coal gas and 2 million c.ft. of water gas, and the normal daily output from 3,350,000 to 4,750,000 c.ft. The entire works plant under winter conditions is run by 73 men. The means available in oven plants for the securing of flexibility in output are described; and reference is made to Mr. W. M. Carr's 1925 Institution paper, wherein he showed that, in certain conditions of the coke market, it would pay to fire the Stretford horizontals with coal gas. The problem is fascinating, and rendered more so by Mr. Gill's optimism as regards the future demand for coke.

Attention to Coal and Coke.

Coming next to the full-size horizontal oven, the author surprised many of his hearers with the information that in America considerably more town gas is supplied by ovens than by retorts. Not only are gas-works themselves adopting large oven plants, but the practice, already extended, of taking a bulk supply from coke ovens is increasing. In the States, of course, the procedure is simplified by the existence of a very high proportion of

carburetted water-gas plant, than which there is no better stand-by in the event of failure of the bulk supply. The careful preparation of the coal and handling of the coke, as practised by oven carbonizers, were described and strongly commended; and the system of first quenching the coke in a wagon, then discharging on to a wharf for cooling-off, was labelled as superior to any method of direct and final quenching on a sloping bench. Sections of the paper were devoted to showing how the Becker patents have aided the uniformity of carbonization, and to the advantages of narrow ovens and small taper. As to suitability of large ovens for gas-works, actual working figures were given relating to the 1300 tons per day Wilputte oven plant in Hamilton; it being explained that the provision of a mechanical producer and the division of the regenerators would convert the installation from a coke plant to a gas-works plant. The yield is 68·6 therms of 592 B.Th.U. gas per ton; and 146 men are employed per 24 hours. In visiting large plants, which give substantially the same yields as retort plants, Mr. Gill gained the impression that in this country we are losing much of the advantage which goes with mere size—an advantage which, he claims, the electricians have found. "But the whole question is intimately connected with the skilful preparation and marketing of coke, which would have to receive as much attention as is now given to the making and selling of gas in progressive and well-managed gas undertakings." The question, however, seems to hold no terrors, or indeed disadvantages, before the big gas men in Germany—judging from the striking statistics advanced by Mr. Gill. He informed the meeting that at the moment no fewer than 2000 large horizontal ovens are on order from the firms of Koppers and Otto in that country—representing a capacity sufficient to carbonize at least 70 p.ct. of the total coal dealt with by British gas-works. It is noteworthy that these firms contract for the repairs and renewal of brickwork over 10 years at the rate of 1d. per ton of coal carbonized.

Others systems dealt with were the vertical intermittent chamber oven and the inclined chamber oven; and his reference to the latter reminded many members of their interesting visit to the La Villette Works in Paris in 1924. The author is of opinion that the inclined chamber oven has claims for all sizes of gas-works; but he concludes his paper by emphasizing the necessity for closely studying each separate situation before pre-conceiving any plan. Such a course was pursued, he says, at Ramsgate, than which no more favourable site for intermittent chambers could be imagined.

Comments.

We gained the impression that the author himself was disappointed with the discussion—not that valuable opinions were not advanced and questions answered, but, as he stated, at the beginning of his paper, it was not intended to contrast ovens with normal carbonizing practice in this country. He had hoped that discussion would take the lines of comparing the various oven units he had described. However, interesting points emerged. The President considers that ovens represent a middle course between pithead carbonization and gas-works treatment; and Mr. Thomas Glover foresees development along the lines of bulk carbonization and continuous treatment in retorts of ever-increasing size. He described his own interesting work with chamber ovens, in which his objective was to supply a coke most acceptable to the nurserymen in his district. Success rewarded him; but he has seen his market affected by the now carefully prepared product of the Midland coke-oven undertakings. New outlets have been found, however, for the vertical retort coke.

The Chief Engineer of the Gas Light and Coke Company finds that all the information published about coke ovens relates to full-pressure production throughout the year, and consequently must be regarded as hardly applicable to gas-works practice. Another stumbling-block, he considers, is that in most instances coal-gas firing is the vogue, which, *inter alia*, must greatly affect data relating to repairs and maintenance. In Scotland, on the other hand, Mr. McLusky finds the main obstacle to be that the best coking seams are already in the hands of the coke-oven owners; he would require 3000 tons a day, and could only obtain 300 to 400 tons. He awaits with faith the result of the co-partnership of continuous and intermittent verticals, the latter dealing with the smalls.

Mr. W. W. Townsend, Mr. Clark Jackson, and Mr. W. M. Carr contributed valuable points; and Mr. R. H. Ruthven promised that Ramsgate should enlighten the industry with the full results of working intermittent W.D. chamber ovens. His evident optimism will be welcome to those advocates of bulk carbonization who find the gas industry in this country slow to consider a system which has taken such a hold elsewhere.

A Tripartite Investigation.

In last year's Fellowship Report, by Dr. C. B. Marson and Prof. Cobb, the results were given of the behaviour of "special" cokes (made by the addition of 5 p.ct. of such oxides as silica, alumina, lime, and ferric oxide, and of equivalent quantities of calcium carbonate and sodium carbonate, to the original coal) during their gasification in steam; and these results showed that lime, ferric oxide, and sodium carbonate had a remarkable influence, giving a much higher steam decomposition with a lower carbon dioxide content in the gas for the same rate of steam supply. The 1927 Report is a continuation of the previous work. In conjunction with Prof. Cobb, Mr. J. A. Sutcliffe, the Gas Research Fellow, experimented on the gasification of the special cokes in steam; Mr. W. R. Branson dealt with the gasification in carbon dioxide; and Mr. F. J. Dent with that in oxygen or air.

Previous experiments on the gasification of these cokes in steam had been carried out at 1000° C.; and attention was directed last year to, among other things, the influence of temperature. It was found that at lower temperatures, varying from 600° upwards, the results were equally striking; a noteworthy feature being the low carbon dioxide content of the gas made at 800° with sodium carbonate coke. Work was then carried out on the effect of lessening the amount of added oxides; and it was shown that the smaller quantities of added constituents had a much more than proportionate effect—which is important from the economic standpoint if additions are to be made on the large scale. The next matter investigated was whether mixtures of constituents would have special influences; but the results demonstrated that mixing brought no particular advantage. All the experiments had been made on coal containing not more than 1 p.ct. of ash, so it was decided to investigate the effect of adding the oxides to a more normal coal containing 4·5 p.ct. of ash. In this case the influence of an added constituent was less, but it was still marked.

Reactivities of "Special" Cokes in CO_2 and Air.

In 1925-26 Mr. Branson demonstrated that cokes known to be highly reactive with steam are also more reactive with carbon dioxide and air. He found that the percentages of carbon monoxide, after passing carbon dioxide at the same rates through different cokes, were 6·6, 29·9, 45·6, and 89·0 for the "pure" coke, iron oxide coke, calcium oxide coke, and sodium carbonate coke respectively. During 1926-27, experiments on the reactivities of the cokes in carbon dioxide were made over a wide temperature range. The addition of 1 p.ct. of iron oxide was found to give more than half the enhanced effect which came from 5 p.ct.; and an impregnated sodium carbonate coke proved almost as active as one prepared by adding the carbonate before carbonization. With some of the special cokes, and more particularly the sodium carbonate coke, there was a falling-off in reactivity to carbon dioxide as an experiment proceeded. Little or no falling-off occurs with sodium carbonate coke with steam.

Working at 800° C., Mr. Dent discovered no differences in the reactivities of the various cokes with air. Above 700° the behaviour of all the cokes is practically the same; but at lower temperatures—400° to 600°—they show wide differences. A remarkable feature was the slowness with which the highly reactive sodium carbonate coke began to react with oxygen; and this phenomenon is being further investigated. It was proved that when air is sup-

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Mr. Sutcliffe is the Gas Research Fellow; Mr. Branson and Mr. Dent are Graduates of the Leeds University. Their collaboration with Prof. J. W. Cobb has produced the subject-matter of this year's Gas Research Fellowship Report.

plied to a bed of coke the temperature attained by the bed is higher when the coke is less reactive.

The work on the influence of the ash constituents in the carbonization and gasification of coal, commenced in 1924-25 by Prof. Cobb and Dr. Marson, becomes increasingly interesting and important. So far, the outstanding feature appears to be the remarkable effect of the addition of sodium carbonate; and the question naturally arises, When can the laboratory experiments be followed by large-scale trials by gas engineers? Dr. Parker, working with a cronite retort, has shown that the addition of 2 parts of sodium oxide to 98 parts of a particular coal results, on carbonization, in a 12 p.ct. increase in gaseous therms. It is unfortunate, of course, that sodium oxide is damaging to the present type of refractory retort; but modifications in plant construction are the outcome of new knowledge, and it would be unwise to regard any plant as representing finality.

Controlling the Properties of Coke.

Introducing the report, Prof. Cobb called attention to the striking differences in the "pure" coke, ferric oxide coke, and sodium carbonate coke when gasified in steam at 800° C. At this temperature the "pure" coke only decomposes 12 p.ct. of steam, and the resulting gases are rich in carbon dioxide. The ferric oxide coke decomposes about 25 p.ct. of steam, but the sodium carbonate coke decomposes about 95 p.ct., and the gases in this case consist of carbon monoxide and hydrogen, with only about 1 p.ct. of carbon dioxide. This indicates the enormous importance which attaches to even slight differences in coke reactivity; and surely as a result of the work being carried out at Leeds some method will emerge of controlling the properties of coke. The experiments were originally undertaken to study the influence of ash constituents in the carbonization of coal, and the results which have already accrued from the investigation fully justify a complete study of the subject. The effects of even small additions of such substances as sodium carbonate are quantitatively very great indeed.

Mr. Sutcliffe and Mr. Branson then summarized their findings, following which the President proposed, and Mr. J. Ferguson Bell, of Derby, seconded, the adoption of the report. Mr. Bell emphasized what an important part the reactivity of coke plays both in its combustion in the open firegrate and in its gasification in a water gas plant. Regarding the latter point, he has found horizontal coke more suitable, on account perhaps of its greater density, than vertical coke for water gas production. Dr. E. W. Smith said that it is unfair of the gas industry to look to the Leeds University for a complete set of panaceas for all their ills. While they are awaiting the results of the researches at Leeds, they ought at least to pay proper attention to the efficient grading, cooling, and drying of coke.

Owing to the short time at disposal for the discussion of this report, Prof. Cobb intimated that he would reply in writing to any questions raised.

Coal Cleaning Conference.

At the commencement of the afternoon session, the President read a telegram of greetings from the American Gas Association, and then broadcasted an invitation to the members from the Society of Chemical Industry to join in the forthcoming Coal Cleaning Conference to be held in Edinburgh on July 7 [see "JOURNAL" for May 11, p. 369].

Economic Cooling of Coke.

In the afternoon the first item was a practical paper by Mr. John P. Leather, M.Inst.C.E., on a branch of manipulative science which appears to be making far greater strides in adoption on the Continent and America than in this country, despite the evident uneconomy and inefficiency of the coke-quenching methods employed by the majority of horizontal retort carbonizers, and the advocacy of "dry quenching" by leading engineers and manufacturers of repute. Waste-heat boilers have been brought to a high state of efficiency for saving heat units from chimney gases; the radiation losses from retort benches, &c., have been reduced by careful insulation; but in this country little has been done, except by the designers of continuous verticals, to recuperate the heat contained in the coke, which the author places at about 25 p.ct. of the heat applied to the setting.

Mr. Leather recalled the process introduced at Liverpool by the late Mr. Edward Allen, and developed further by Mr. Gibson, who described it in his paper before the Institution in 1924. In this, the coke is deposited, by a "G.N." transporter, into a container, which is sealed and immersed in a tank of cold water. The heated water is used for boiler-feed purposes; and the coke, besides being dry, has the advantage of a greatly improved appearance—as was seen from samples exhibited at the meeting.

Sulzer and Collin Processes.

The author then passed to a description of three systems with which he is well acquainted; the first in order being the Sulzer plant. In this, the hot coke is introduced, by skip-loads, into the upper part of a chamber; corresponding quantities of cool coke being intermittently withdrawn from the lower part of the cooling chamber. During its passage through the chamber, it is cooled by a current of inert gases continuously circulated by a fan through the coke, a superheater, and the firetubes of a boiler. The

paper next describes the Collin plant at the Hattingen Coke-Works, which deals with the coke from a battery of 50 chamber ovens; one cooling receptacle serving for three carbonizing chambers. The principle is the same as in the Sulzer plant; but the process is fully intermittent, as the charge of 8·3 tons of coke is completely evacuated after four to five hours in the cooling chamber. In both these processes, the circulating gases are derived from air; slight combustion of coke quickly converting the oxygen to oxides of carbon. In the Sulzer process, it is now standard practice to admit a regulated quantity of air to burn, and so prevent an inadvisable accumulation of, any hydrogen which may remain in the coke. Without this admission of air, the process can claim an efficiency of 80·6 p.ct.

The Heller-Bamag Plant.

The third system described by Mr. Leather was the "Heller-Bamag," an illustrated article on which was communicated to the "JOURNAL" for July 14, 1926. This ingenious process is not strictly dry, as it comprises the spraying of the incandescent coke in a closed cylinder with water at 260° Fahr., with the resulting production of steam and water gas which pass direct to a boiler, thence to a counterflow water heater, after which the uncondensed gases are mixed with the coal gas. However, when steam evolution ceases and the charge is removed, the latter is still at a temperature of about 360° Fahr., so that any water should be evaporated. The author points out that the gases generated can be lighted by a match; and the Bamag-Meguin Company's analysis gives a calorific value of 295 B.Th.U. per c.ft. With coke at 1000° C., it is claimed that about 1715 c.ft. of this gas and 660 lbs. of steam are produced per ton of coke. A special bronze is used for the boiler and superheater tubes and connecting pipes; and the design of quick-closing door to the spray chamber is of great interest.

Concluding his paper, the author stresses the value of dry coke by giving figures which show a depreciation of 11 p.ct. in net heating value due to the presence of water. He enumerates the following advantages of employing a dry cooling process: Higher C.V. of the coke; smaller percentage of breeze (water quenching disintegrates the lumps); a substantial saving in water; an increase of 6 p.ct. in coke for sale, owing to the production of steam, as by the Sulzer process.

The Principle Accepted.

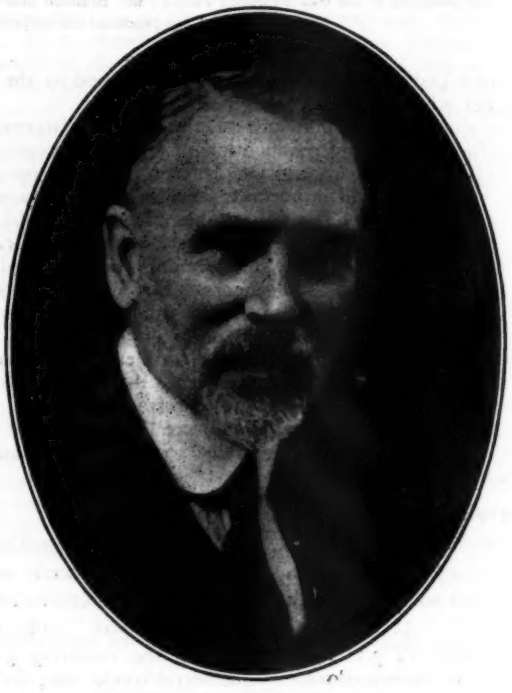
The main feature of a somewhat disappointing discussion was the reiteration of the assertion that "dry" coke cooling is now a necessity. The President considers that too much cannot be said for dry coke; Mr. Gill says dry cooling is bound to come in some form or other; Dr. E. W. Smith is fearful of the topic being allowed to recede from the prominence it has recently enjoyed, for he has been tremendously impressed with the contrast between the troubles of those who treat coke seriously and those who take no pains. An interesting discussion took place as to the amount of steam available from dry cooling of coke at normal gas-works temperatures; and other important points were the dust nuisance and the payability of the process. As regards the financial return, opinions differed; but it is the plain fact that all installations which have been put in abroad and here have been considered from this point of view, without being found wanting. Mr. Leather and Mr. J. W. McLusky were able, at any rate, to testify to the financial soundness of the Burnley and Glasgow jobs respectively.

A notable contribution to the discussion was made by Mr. J. H. Clegg, of Burnley. He discounted the dust nuisance from the Sulzer plant; and as regards the danger of air leaking into the container and burning the charge, he pointed out that steel is now being employed for the container shell, and that cracking has thus been done away with. As for the general results obtained, it must be remembered that the problem with gas retorts was a very different one from dealing with (say) 6-ton draws of coke, which was the case at Utrecht; but they had a paying proposition at Burnley. Mr. Clegg cited a further advantage of dry cooling—the absence of acid fumes, which were so deleterious on a works. He had not so much faith in the future of gas coke as to overlook the necessity of supplying a material suitable for all purposes.

Refractory Materials.

Mr. J. P. Leather then presented the Report of the Refractory Materials Joint Committee of the Institution and the Society of British Gas Industries, prefacing his remarks with a reference to the loss the industry has sustained by the death of Mr. Albert Cliff. The Committee have this year again been considering the clauses in the Standard Specification dealing with the after-expansion of silica test. But further data are necessary; and the Refractories Research Association have been asked to carry out a series of tests on as large a variety of silica bricks as possible. In place of the detailed reports of the B.R.R.A.'s researches, with one exception, only concise summaries of the lines followed and the practical findings are this year included—an innovation which was widely approved by the members of the Institution.

These summaries were seven in number; and in the first Mr. A. E. J. Vickers, M.Sc.(Lon.), A.I.C., briefly explains the lines along which investigation is proceeding to determine the effects of furnace atmosphere upon re-



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fractory materials. It is pointed out that the matter is of great importance to the gas engineer, since all his refractories either contain iron or acquire it in use; and in practice they come into contact with oxidizing or reducing gases. Mr. Vickers' second contribution was a summary of the B.R.R.A. Bulletin 14, on "Sillimanite Refractories," which reported the work of three chemists. Mr. W. J. Rees finds that sillimanite bricks are of little use when exposed to ferruginous slags, but may be of great value in the glass industry and in cases where high temperature alone has to be resisted. Mr. T. F. E. Rhead says that its great density is one disadvantage of the material, but points out that, in the modern type of regenerative coke-oven, the flue system throws no load on the main structure, and that any oven can be relined without interfering with the battery as a whole. Mr. Dale reported on the properties of a sillimanite brick under load and at a high temperature.

The next three summaries—all by Mr. A. J. Dale—deal respectively with siliceous products, quartz-clay mixtures, and firebrick material. The chemical composition must be regarded as subsidiary to physical composition in the intermediate group of refractories (75 to 92 p.ct. SiO_2—which has not hitherto been dealt with in the reports submitted to the Institution), as far as load-bearing capacity

is concerned. The fourth summary records interesting and valuable conclusions drawn from the investigation of the load-bearing capacity of mixtures of quartzite and fireclay; and the fifth contribution suggests that highly aluminous bonds of pre-fired diaspore clay and ball clay may well be applied to certain zones of gas retort and other constructions where silica shapes are prone to spalling.

The Holing of Silica Retorts.

The next section is much longer, being a compilation by Mr. Dale of valuable information relating to the corrosion and holing of silica retorts. The main part of the section is, in fact, a transcript of a paper by Mr. H. V. Corfield, before the Eastern Section of the Southern Association of Gas Engineers and Managers, and of the ensuing discussion. Mr. Corfield's subject was "The Premature Holing of Silica [Horizontal] Retorts;" and his experiences related to a setting which was let down after a run of 236 days. Detailed examination led to the deduction that iron in some form was probably the cause of the failure—holing in the bottom tiles of the retorts. The possibility of iron in the original silica was not overlooked; but the probability appeared to be that it was either in the coal as supplied or shed in the form of nuts and bolts from the charging machines, &c. The discussion on Mr. Corfield's paper produced much of interest, but no definite conclusion; and a laboratory examination of his samples was carried out. This left uncertain the cause of the initial corrosion, but showed that the hollow or roughness, caused initially, collected corrosive ash which intensified the process. The facts established and the suggestions deduced, as regards both horizontal and vertical silica retorts, are concisely set out by Mr. Dale. The collection of data and laboratory work is being continued.

The final section of the Report cites other investigations which have been published.

"A Keystone."

After Mr. Leather had introduced the report, and drawn attention to its salient features, the President opened the discussion by remarking that he looks upon refractories as constituting a keystone to the science of carbonization. He considers that the research merits far more support than it receives. Further information regarding the failure of the silica retorts was supplied by Mr. Diamond, who was one of those responsible for the actual tests. He was now able to state that some of the silica jointing material supplied to them had been shown to be deficient in adhesive property, with the result that furnace gases found a passage through the wall, and initiated the trouble. He explained the appearance of the failure near the ends of the retorts by the greater vacuum in those zones, and the consequent readier intake of the furnace gases.

Mr. Gill was again able to supply interesting information from abroad. In Germany, it appears, 95 p.ct. silica is being used almost exclusively for all types of plant; and they have been able to dispense with allowing for permanent expansion by paying greater attention to burning-off, which is usually carried out in highly efficient tunnel kilns. He criticized the absence of an under-load test—a point with which Mr. Leather dealt in his reply. Finally, Mr. Botley appealed to the industry for the general putting-forward of experiences, so that they may be the subject of research for the common weal.

Gas Service.

The final session of the Business Meeting, on Thursday morning, was occupied chiefly with that most important subject—service; Mr. J. H. Canning, of Newport (Mon.), presenting an admirable paper, in which he dealt with the accomplishments of his Company and the *raison d'être* of service to the consumer. This he did in such a manner as to obliterate any idea that it represents an ideal attainable only by the larger undertakings. Indeed, one almost received the impression that service to the consumer, and the latter's consequent goodwill, are easier to achieve by the internal co-operation and personal touch methods of a small concern than by the necessarily highly organized offensive of a large undertaking. However, the main thing is that the expediency of service has been accepted by the greater part of the gas industry; and the latter has now reached the stage of discussing "the extent of its application, and the best means of giving it effect."

Mr. Canning dealt first with the foundation he considers necessary for any scheme of service—namely, a supply of gas satisfactory in quality and in quantity at full peak load; and, arriving thus straight-away at service pipes, he remarked upon the inevitable accumulation of work which awaited the majority of gas undertakings after the war. Since 1919, the Newport Company have relaid 3144 services, at the same time increasing the size from ¾ in. to a minimum of 1 in. to allow for future development. As regards maintenance, the Company can claim to have practised it in the days of the flat-flame burner; and as long ago as 1892 a campaign which has continued till the present day was initiated against the water-slide chandelier. Incandescent burner maintenance was started in 1898, at a charge of 2s. per burner per annum; and this remains the figure to-day, per nozzle, with free mantles, cleaning, and adjustment. The Company will not undertake the maintenance of worn-out or defective burners; but take note of cases, and leave them to be dealt

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with by a special canvasser with a hawker's licence. In 1926 he disposed of no fewer than 815 burners; and the figures for other appliances are even more remarkable—including, for instance, 60 fires and 667 globes and shades. There is as yet no definite system for appliances other than lighting burners; but, as far as possible, each case is treated independently.

Systematic inspection of appliances was adopted after the war in Newport, when numerous bad cases had come to light, which had developed during the war-time shortage of materials and labour. The first object in view was the elimination of actually dangerous installations; and 210 inspections were made per week, at a cost of 5d. each.

Testing and Standardization.

Mr. Canning's examples of amateur gasfitting are hair-raising; but he closely associates the question of eliminating amateur efforts with that of testing fittings generally, and ensuring that only high-class goods are employed. In Newport they test some 12,000 fittings a year, and the cost of doing so is a mere £40; and co-operation with the makers has resulted in the percentage of rejects falling from 1·07 to 0·28. It is Mr. Can-

ning's opinion, however, that appliance makers should themselves shoulder the responsibility for testing and guaranteeing their goods. A fruitful source of deficiency in gas apparatus since the war has proved to be the taps; and the author devoted an interesting section of his paper to an examination of the matter, concluding that there would be profit in reverting to the old practice of a 1 in 12 to 1 in 16 taper for taps, which of recent years has tended to something far steeper. At the same time, the suggestion is put forward that the Institution of Gas Engineers and the manufacturers might well co-operate in standardizing the material and the wearing parts of taps and fittings generally. In any case, the co-operation of the manufacturers is essential; and, as they do not as a rule come into contact with the consumers, it is up to gas undertakings to advise them of the working of their appliances on the district.

The system of inspection found necessary after the war has been continued, with the view of maintaining the efficiency and keeping a census of appliances; and when obsolescent apparatus is found, the canvasser follows up the inspector, and is able to offer the encouragement of free fixing for apparatus bought for cash or on hire-purchase.

"Old-Fashioned Courtesy."

As regards the qualifications of those who come in contact with the consumers, first place is accorded to what the author terms "old-fashioned courtesy," which is "generally accompanied by intelligence." Sound technical knowledge is the other essential; and this is ensured in Newport by classes, which were started in 1912, and have continued to the present except for a break from 1917 to 1919. Their post-war resumption was hampered by the difficulty of finding candidates with a high enough standard of general education; but excellent results, albeit with a smaller number of apprentices, are secured now by co-operation with the headmasters of the Municipal Schools, &c.

At the conclusion of this most useful contribution, Mr. Canning summarized his arguments in favour of service, and, from his individual experience, laid down the following desiderata for any scheme:

1. It requires the sound foundation of adequate gas supply.
2. It must be the outcome of special study of local conditions, and may advantageously be applied by stages.
3. It must be worked on business lines—with flexibility and no red tape.
4. It must as far as possible preserve the feeling of personal touch.
5. The service must be rendered willingly.
6. It requires the education of the consumers, and
7. The education of the staff.
8. There must be, throughout the gas undertaking, unity of purpose to make the scheme successful.

A Very Live Topic.

Enthusiasts on service in its various forms to the consumer—and among enthusiasts we modestly class ourselves—were highly gratified at the reception accorded Mr. Canning's paper, and at the way in which members almost "queued up" to take part in the discussion. The topic has indeed taken a firm hold upon the industry, which has definitely reached the stage of discussing ways and means of fulfilling the accepted principle of service. How to "charge" for service? Employ what man for the job? Hire or hire-purchase? Universal or selective? These and many other questions regularly arise in discussions on the subject; and while it is of undoubted good to "give them an airing," nevertheless the answers must depend largely on local conditions.

As for the discussion, this review cannot do more than indicate one or two points on which special emphasis was laid. For instance, both the President and Mr. Goodenough shrank from the thought that the statement should spread abroad that the gas industry had adopted maintenance by force of competition. As Mr. Goodenough says—service is a duty, apart from any question of competition; it is both right and profitable in itself. The most difficult thing to settle in the matter of inspection and maintenance is probably the type and the source of the men who make contact with the consumers. Shall they be ordinary fitters, specially trained lads, or young women? Much was heard in this regard last Thursday. A special pointer may be made here to Mr. Morland's scheme for saving road excavations, and to Mr. Shaw's admirable contribution, in which he startled some men by apportioning 75 p.ct. of importance to distribution, and 25 p.ct. to the works.

The discussion as a whole was worthy of the excellent paper, and merits the study of all.

New President and Vice-President.

Intimation was made by the President on the morning of the first day that Mr. H. D. Madden had been elected to succeed him in the Presidency, and that Mr. John Terrace had been elected a Vice-President through the elevation of Mr. J. W. McLusky to the Senior Vice-Presidency. The early intimation was heartily welcomed, but was not in accord with the programme. At this point,

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The New President.

the President acknowledged this, and gave a complete list of the new officials of the Institution, whose names were greeted with a fervour which almost suggested that the elections were news to them.

With that sincerity which is of his nature, Mr. Madden thanked the members for the honour they had conferred upon him; and he promised to uphold the traditions and dignity of the high office, though he realized how difficult it would be to live up to the standard set by his predecessors. Not only his Company, but the city and the Principality of Wales, regard his election as a great honour. He also stated what we had not realized before, that this was the first time in the history of the Institution that the members had crossed the Severn into Wales for a President. He concluded his remarks by extending a cordial invitation to the Institution to visit Cardiff next year. He assured the members that their welcome would be warm. His Directors had said to him: "This is a great honour to you, Madden, and the Company; will you let us share it with you?" There was loud applause, which only subsided when Mr. John Terrace rose to thank the members for placing him in the honourable position of a Vice-President. He expressed the pride he felt—more

particularly seeing that the honour had not been sought by him.

The President's Certificate.

Throughout the closing scene much was said of the great ability that Mr. John Wilkinson had displayed during his occupancy of the Presidency; and, in most graceful terms, Mr. Madden handed to Mr. Wilkinson the President's certificate. He had added prestige to the position, and throughout the year he had struck a kindly personal note at the meetings of the Council, and in the performance of his other duties. This encomium was endorsed by great applause. The year of office is one upon which Mr. Wilkinson confesses he will look back with memories which will be ever cherished.

Votes of Thanks.

There came from Mr. Brearley a composite resolution which recorded the thanks of the members to the Council, the Honorary Secretary (Mr. W. E. Price), the authors of papers, the Research Committees, the Scrutineers, and the Auditors. Mr. Brearley referred in terms which faithfully represented the views of the members to the work of each and all. Mr. Ralph Halkett was the seconder of the motion, which was carried by acclamation. There was response by Mr. Botley for the Council, by Mr. Price for himself, by Mr. Carmichael for the authors of the papers, and by Mr. Samuel Glover for the Investigation Committees. Thereafter, Mr. Walter T. Dunn received the acknowledgments of the members for his loyal services. Subsequently the members recorded their warm thanks to the Council of the Institution of Electrical Engineers for their courtesy in permitting the use of their premises for the meeting. What they will not allow is any more material recognition.

Place of Next Meeting.

After Mr. Madden's invitation, in the name of his Chairman and Directors, to the members to hold their next meeting in Cardiff, the formality was gone through of deciding, on the proposition of the President, heartily to accept the suggestion. This is the best acknowledgment of appreciation.

Thanks to the President and Mrs. Wilkinson.

On the proposal of Mr. J. E. Blundell, of Carlisle, seconded by Mr. John Wilson, of Motherwell, the members registered their hearty thanks to the President for the dignified manner in which he had conducted the proceedings of the conference, and to both him and Mrs. Wilkinson for their bountiful hospitality on Tuesday night.

With the President's reply, a meeting closed which, for sustained interest, numbers in attendance, and fruitfulness, it would be difficult to match from Institution history.

SOCIAL EVENTS.

RECEPTION AND DANCE.

There was a gay gathering at the Connaught Rooms on Tuesday evening, when the President and Mrs. Wilkinson charmingly received upwards of 500 guests. The well-known ballroom was florally decorated for the occasion, and round the sides and in an ante-room were tables laid for the refreshment of the guests. Among those present we met the President of the National Gas Council (Sir David Milne-Watson), the President of the British Commercial Gas Association (Sir H. W. Russell Bencraft, M.R.C.S.E., J.P.), Sir Albert Ball, Mr. W. J. Atkinson Butterfield (one of the Gas Referees), Dr. C. H. Lander, Director of Fuel Research, Prof. Cobb, and other representatives of his Department at the Leeds University, representatives of the Councils or officers of the National Gas Council, the British Commercial Gas Association, and the Society of British Gas Industries. This was an occasion when the co-operative spirit which exists in the gas industry was prominently in evidence.

When all were assembled, a photograph was taken, with the President and Mrs. Wilkinson in the midst of their guests. It was a striking scene. A charming incident was the presentation, by the Midland Association of Gas Engineers and Managers, of a lovely bouquet to the President's wife. From 9 o'clock till midnight, there was dancing to excellent music, and though a few guests from a distance had to tear themselves away before the close of the enjoyable evening, the greater number remained until the end, and were loath to part from the pleasure which had been so hospitably provided for them.

PRESIDENT'S LUNCHEON.

On the invitation of the President and Council of the Institution, a large party sat down to luncheon in the Savoy Hotel at the close of Tuesday morning's session. The President (Mr. John Wilkinson) occupied the chair; and there were with him at the top table Sir Albert Ball, J.P., Sir Fortescue Flannery, Bart., Sir H. W. Russell Bencraft, M.R.C.S.E., J.P., Sir Arthur Duckham, K.C.B., Sir Alexander Gibb, Prof. Arthur Smithells, C.M.G., Dr. C. H. Lander, Prof. J. W. Cobb, C.B.E., Mr. J. F. Ronca, O.B.E., Mr. A. Abbott, C.B.E., Mrs. M. A. Cloudesley Brereton, Mr. F. W. Goodenough, C.B.E., Mr. John F. Simmance, and Alderman Fred West, C.B.E.

The Loyal Toast was duly honoured at the call of the President.

Fuel Research.

Sir ARTHUR DUCKHAM: I have been asked to propose the toast of "Fuel Research." It is the first time I have seen it on a toast list; and I am glad to be here to submit it. I think we may say that all of us in this room—except perhaps Sir Albert Ball—are dependent upon fuel research for our livelihood; and so it is of the utmost importance to us. Most of us are keenly interested in it; and I feel sure that as time goes on there will be greater and still greater keenness shown by our industry with regard to this subject. We all realize the necessity for further work upon it, although there is already a great deal of fuel research work being done. It has been extremely interesting on the Fuel and Power Committee to find various persons and organizations coming forward with their views on fuel research; but it seems to me that the thing necessary in this research, as in other researches, is greater co-operation and co-ordination. The Institution of Gas Engineers has its own Research Committees; but I feel that every one of us, each in his own way, has his own research work, and I am not at all sure that the result of this research is made use of in the way it should be. Things that occur on the works, the problems that have to be met, the failures that become apparent—all these are of vital interest to us collectively as well as individually. But we sometimes forget that research work of this character is so important to our neighbours and to others in the industry. I do feel very strongly indeed that we as an Institution should be in a position to receive and co-ordinate results obtained by engineers and chemists in researches of this kind. We all have our troubles. Either fortunately or unfortunately for me, I am in a position to share troubles with quite a lot of gas engineers. They often say that if they want to see me it is only necessary for them to have a little bit of trouble, and they will get me. [Laughter.] In this way, I see many of the troubles of the industry; and I feel much more could be done if these troubles could be brought together and the causes of them shown clearly. Look at what the Gas Light and Coke Company, the South Metropolitan Gas Company, Birmingham, Sheffield, and similar large concerns, have done and are doing. Yet what do we know of the work of these undertakings? I think of the tremendous amount of knowledge all these people possess which would be of very great use to the gas industry as a whole. Again, take the contracting side. If the knowledge gained in surmounting the troubles which I, and I am sure Alderman West and others, have gone through could be

brought together for the benefit of the whole industry, I feel that a great deal of good would be accomplished.

A MUSEUM OF REFRACTORY FAILURES.

For example, a tremendous lot of work has been done on refractory materials; and if this could be brought together for the assistance of our great industry, it would be most valuable. I have even gone so far as to envisage a museum of refractory failures, with some one in charge of it possessing full knowledge of the subject, which knowledge he could make known to all of us. I can quite imagine an engineer in trouble coming to this museum and inspecting the refractories on view, so as to ascertain whether his trouble had occurred elsewhere, and, if so, what were the reasons. Fuel research has been associated for a good many years now with the Fuel Research Board; and I am coupling Dr. Lander's name with the toast. All that need be said of him is that we know nobody else we would rather have in the position which he occupies. ["Hear, hear."] He is a friend at all times. He is quite un-Governmental. I think that is a compliment. He is out to help us; and he is always willing to show us what is being done—which is most important. You who have been to the Fuel Research Station realize what has been accomplished; but I feel that, if it were possible, the Fuel Research Board should be in even closer touch than at the present time with the various fuel industries. I would like to see Dr. Lander or one of his staff on every research body attached to any Institution or Association having fuel interests. I would like to see our work and our troubles brought to his attention more and more. He and his Board are only too delighted to be made to realize the troubles and difficulties of the fuel industries; and I am certain that if they see their way to help in any direction they are only too glad to come forward and do what they can within their limited sphere. Finally, I would appeal to this Institution of ours to make a powerful move to strengthen fuel research, which is the basis of our lifework, and to do all in its power to get together for the benefit of the industry the knowledge that is being gained every day in all kinds of circumstances.

FUEL THE BASIS OF CIVILIZATION.

Dr. C. H. LANDER (Director of Fuel Research of the Department of Scientific and Industrial Research), in the course of a witty reply, said: Sometimes when one attends a luncheon of this nature, one feels in a rather difficult position, when certain toasts have been proposed, as to whether or not one should keep one's seat. On the present occasion, I believe I am the only one in the room who kept his seat. I think that is wrong. True, my name is coupled with the toast; but, as Sir Arthur Duckham has pointed out so ably, fuel research covers a very wide field. It covers all your activities in the direction of research; and I venture to think that it covers all your commercial operations of every kind. Therefore, if the matter had been pursued to a logical conclusion, it would have placed Sir Arthur Duckham and all of you in the awkward dilemma of having to remain seated and stand at the same time. [Laughter.] Sometimes we are rather apt to take a narrow view of what research really means. That is perhaps inevitable, owing to the way in which science in industry has grown up. To my mind, fuel research is a subject we are all concerned in—even to the most junior clerk in a gas company's office, or somebody occupying the same kind of elementary position. Food is the basis of life; we share our requirements for food with the animal kingdom. But man is the only genus that has ever, as far as this planet is concerned, found the way to provide power, light, and warmth by artificial means; and in that way fuel is the basis of civilization. Research is only completed when it has been brought to practical fruition, and the results applied generally or where they can be applied. We are sometimes rather apt to talk about the difference between the scientific efficiency of a process and the commercial efficiency. I claim that commercial efficiency is the only true criterion of scientific efficiency. ["Hear, hear."] Imperfect as it may be, the balance-sheet of a process is the most scientific measure we have for judging the efficiency of that process. I thank Sir Arthur Duckham for the kind manner in which he has proposed this toast, and you, gentlemen, for the manner in which you have received it.

"THE VISITORS."

Mr. H. D. MADDEN, proposing the toast of "The Visitors," said: I would prefer to call the large number of visitors present our friends rather than our guests. They are the friends of the industry; and it is well that we should have a great many friends. Among those whom the President has received to-day are visitors from La Belle France; and I am sure we are delighted to have them with us. The spirit of international co-operation will do much to clear away ill-feeling between the different nations at this time. I think science will only go forward with the aid of mutual goodwill; and it is very helpful to have these guests here to-day. We have with us representatives of kindred Associations, which we are delighted to find joined with the gas industry. The chief guest we have with us to-day is Sir Albert Ball, whose name I have to couple with the toast. The name of Ball carries our minds back to the time of the war. He himself has rendered great public service to the City of Nottingham; his son, of revered memory, will live down through the ages as one of our foremost airmen.

FOSTER THE EDUCATIONAL SIDE.

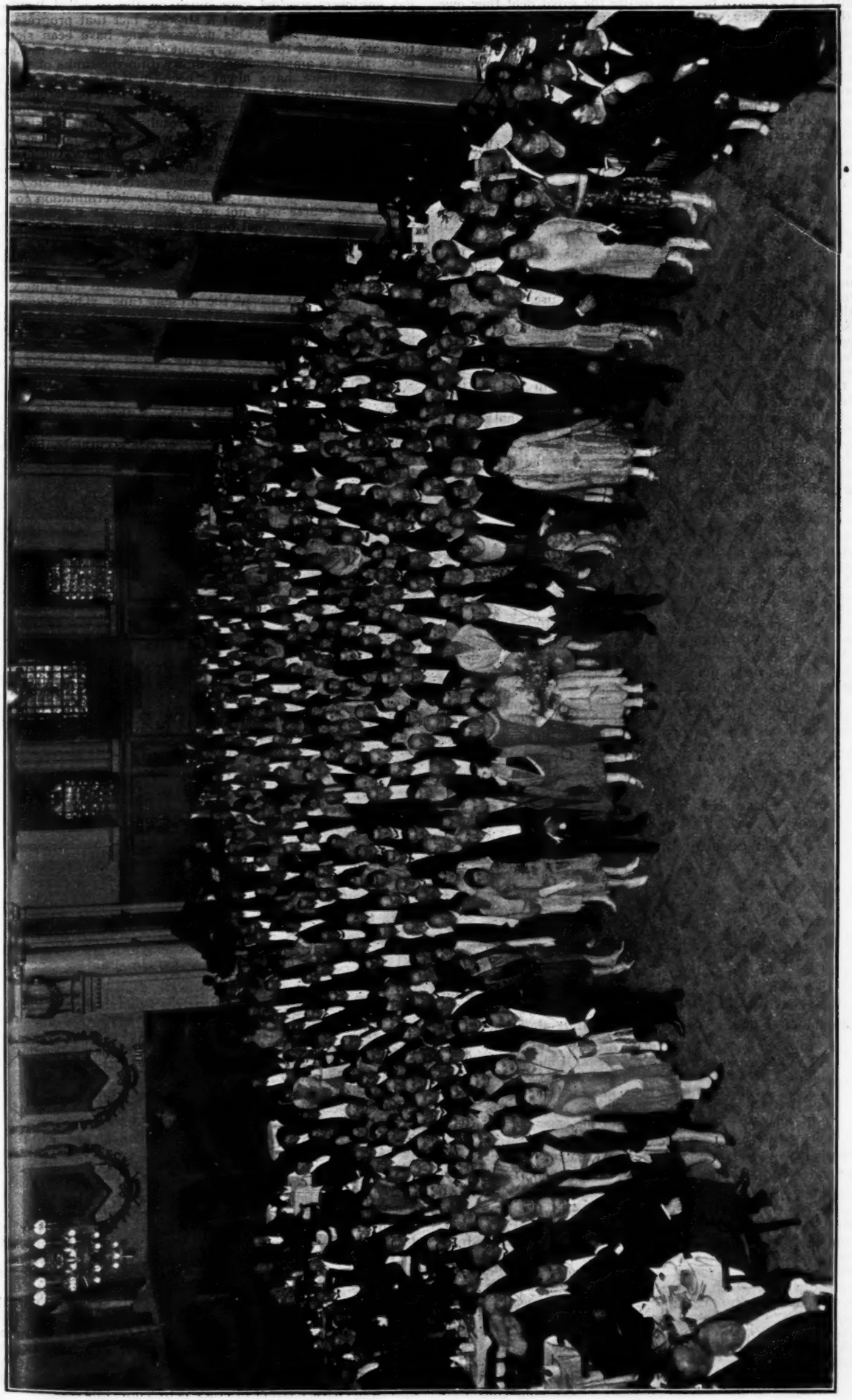
Sir ALBERT BALL, J.P. (Chairman of the Nottingham Corporation Gas Committee): I am very glad to have my name coupled with this toast, and to reply for the visitors. I have been most interested in the proceedings. Sir Arthur Duckham said that I was the only person in the room who had made nothing out of fuel research. I certainly have made nothing out of fuel research; but I have been very interested in your industry. I have realized, after many years' experience as Chairman of the Nottingham gas undertaking, the important part that gas plays in industry and in the home life of the people. I do sincerely hope that you who are responsible, not only for the present, but also for the future prosperity of the industry, will see to it that the educational side is fostered and encouraged to its utmost limit. I was delighted to gather from what Mr. Goodenough said this morning that the educational side is being pushed. This is essential, because if you make good gas—and I do not say that you ever make any bad gas—unless it is distributed properly your product will often be condemned when it is the fault of the fittings and internal piping of the premises you supply. My experience has been—and I have had some experience with gas fittings, if not with gas making, because my early days were spent in that much abused trade of plumbing—that the blame for difficulties has been attributable to the men who piped the buildings, rather than to the men who supplied the gas. I often think it is a great pity that we have not generally in the gas industry regulations stipulating the size of internal piping that must be used. If we had similar rules to those applying to the water industry, we should not have one-half of the trouble or a tithe of the expense we are put to in rectifying complaints that have nothing to do with the manufacture of gas. ["Hear, hear."]

PROUD OF THE PRESIDENT

I am very proud to-day to be sitting beside the President of the Institution of Gas Engineers. Something like fifteen years ago it was my pleasure to interview several applicants for the position of Gas Engineer and Manager to the City of Nottingham. Now, I do not believe in going in "school-party fashion" to interview people; I like to make it a personal matter, and I remember calling in this way to see Mr. Wilkinson at Halifax. He came in with his hat stuck at the back of his head, and looking to have enough "go" in him for half-a-dozen men. I immediately thought to myself: "This is the chap for Nottingham." He was appointed; and we have been delighted with our choice. We have found Mr. Wilkinson the soul of honour—as you, I know, have found him, as President of this Institution.. ["Hear, hear."] We have found him a capable engineer; a man desirous of doing the best he can for the industry, and at all times trying to be fair with every man in the undertaking, from the highest to the lowest. He has always been most tactful and resourceful. I regard him as being a credit to your profession. I sincerely hope that he will spend the remainder of his days with us, and that his son will follow in his father's footsteps as an ornament to the profession.

FROM STRENGTH TO STRENGTH.

Sir H. W. RUSSELL BENCRAFT: The privilege granted to me to propose the toast of "The Institution of Gas Engineers" is possibly by reason of the fact that I am this year President of an Association that is one of the offsprings of your virile Institution—namely, the British Commercial Gas Association. Your Institution is nearing the age of three-score-years-and-ten, when it is said of man if he passes that age "Then is strength but labour and sorrow;" but you, on your part, with advancing years, go from strength to strength. The evidence is plain to all who study your annual reports, and see the outcome of the work of the many Committees who are engaged in research work all for the advancement of the industry which you so worthily represent. Then look at the programme prepared for your members for the conference opened this morning. It is ample evidence that your Institution does not represent a dying industry, but, on the other hand, is one which, in spite of its years, retains full possession of all its mental and physical powers, and is successfully upholding the good work done by some of your former Presidents—Thomas Hawksley, your first President, Sir George Livesey, Sir Corbet Woodall, Thomas Newbigging, John West, and many others whose names are more familiar to you than to me. If evidence were required as to the value of your Institution to the gas industry, it was amply provided by the work done by its members during the period of the great war. Without the valuable work done by your members from the inception of the Institution the gas industry would not have been so prepared as it was to shoulder the tremendous burden thrust upon it at a moment's notice. It can, I think, be truly said that gas and its many bye-products were largely instrumental in deciding the victory in favour of the Allies. Then, again, gas helped in a very large measure last year to assist the nation through the difficulties brought about by the coal stoppage. Speaking as a layman, I think both the Government and the



THE GUESTS OF THE PRESIDENT AND MRS. WILKINSON AT THE RECEPTION.

country at large have failed to realize the great debt they owe to the gas industry; and it is mainly owing to the natural modesty of those who manage its concerns. It seems as though all of you invariably belittle the good deeds you do; and even when they are referred to by the outside world, you maintain a discreet silence or say: "Pray do not mention it; I prefer to hide my light under a bushel." However, some day there will arise a trumpeter who will insist in proclaiming your good work to all and sundry; and then the world will say: "We must kill the fatted calf, and do honour to those who, whilst giving light to all the world, have themselves sat in darkness."

SOUTHAMPTON.

I am pleased to have the honour of submitting this toast for several reasons. First, I find it was 25 years ago that Mr. S. W. Durkin, a former Engineer of the Southampton Gas Company, was your President, or rather President of the Gas Institute—the forerunner of your present Institution. Your meeting that year was held in Southampton; and in October of this year I hope to have the pleasure, as President of the British Commercial Gas Association, of welcoming you at Southampton at the Annual Conference of that Association. [Applause.] In the year 1902 a worthy predecessor of your President passed to his long rest—namely, the late Mr. W. R. Chester. Your President at that time was making his way up the ladder of fame; and that he was built of the right material is proved by the position he holds to-day. It shows the truth of Napoleon's saying: "There is a marshal's baton in the knapsack of every soldier." The address delivered by your President this morning is ample evidence of the wise choice made when you selected him to occupy the Presidential Chair. In submitting the toast of "The Institution of Gas Engineers," I have the greatest pleasure in coupling with it the name of your worthy President, Mr. John Wilkinson.

THE INSTITUTION.

The PRESIDENT: I desire at once to express the sincere thanks of the members of the Institution to Sir Russell Bencraft for the eloquent terms in which he has proposed the toast. I heard for the first time from his lips that I follow in the steps of a gentleman who has always been honoured in the gas industry. I refer to Thomas Hawksley, who apparently was the first President of this Institution and was an engineer at Nottingham. The Institution was formed in the year 1863, under the name of the British Association of Gas Engineers; and from that time its members have been carrying out—more or less successfully—fuel research and coal conservation. There may be considerable truth in the statements which one hears from time to time that in the old days the gas engineers worked very much on the so-called "rule-of-thumb" methods; but it is a striking fact that progress was always taking place. This progress may have been slow in the early days of the industry; but it was sure. In my judgment, there is ample evidence that within the ranks of the gas engineers there have always been men endowed with the necessary brains and determination, who were prepared to risk their reputations by undertaking experimental work for the purpose of obtaining improved results. The industry had only been in existence a few years when an attempt was made in the year 1823 to substitute fireclay retorts for the original cast-iron retorts. Such was the beginning of our research work; and, although these early efforts were unsuccessful, disappointment simply strengthened the determination to succeed. The course was not an easy one; but stage by stage the carbonization of coal on gas-works has developed in such a way that we can say to-day, with the utmost confidence, that the gas industry manipulates coal for the purpose of producing light, heat, and power more efficiently and, equally important, more economically than is possible with any other process in general use at the present time. This is due undoubtedly to the many important uses for which our so-called residual products are required; and it goes to prove that the carbonization of coal must be classified as a key industry. The sister industry—electricity—provides light, heat, and power; but the gas industry covers a much larger field of usefulness.

COAL CONSERVATION.

We cannot stress too strongly the fact that our industry also provides the facilities for many other industries to practise what so many people preach—sometimes accurately, but more often inaccurately—namely, coal conservation. It must not be thought, however, that gas engineers have any desire to claim that they have attained this position entirely by their own efforts, for such is not the case. Gas engineers generally know what they want; but if they cannot obtain it themselves, they do not hesitate to call in outside assistance. It would appear that the formation of our Institution in 1863 was the result of a realization by the gas engineers of those days that combined effort was an improvement upon individualism; and we have always realized that we are much indebted to many friends—commercial, industrial, and technical—who have done much in the way of furthering our efforts to make the most of what is probably our country's chief asset—namely, its coal deposits. It is for this reason that we welcome your presence with us at this gathering. We know that business to-day—if it is to be successful—means strenuous effort; and we realize that you have made some sacrifice in order to be present. We therefore take this opportunity to thank vou for the assistance you have given to us in the past, and express the hope that you will not fail us in the future.

THE VISIT TO NOTTINGHAM.

An account of a visit of the members to Nottingham appears after the full report of the General Proceedings of the Meeting.

RADIATION FROM GASES.

[Communicated by the Massachusetts Institute of Technology.]

> In a covering letter our correspondents say: "The design of furnaces has been hampered in the past because the observed and calculated heat transfer coefficients have been in serious disagreement. The work of Mr. Hottel is a major factor in reconciling the calculated with the experimental coefficients."

Of the recent contributions from the Department of Fuel and Gas Engineering of the Massachusetts Institute of Technology, a paper by Hoyt C. Hottel on "Radiation from Gases," which is to be presented in the near future before the American Institute of Chemical Engineers, is among the most important. In the past, it has been customary to neglect radiation from gases in problems of heat transmission, due to the complexity of the computations involved. Hottel, however, has derived a number of charts which make it possible to calculate this radiation without difficulty. He has shown by a number of practical examples that this factor is far from negligible, and, in fact, in many cases is even greater than the transfer of heat by convection. His charts will be of great assistance in the design of any equipment involving heat transfer from gases. It has been known, for example, that the heat transfer coefficients actually found in the convection tubes of cracking coils were larger than those calculated from the usual convection formulæ, and it was therefore impossible to compute with any degree of accuracy the number of tubes required. By combining Hottel's charts and the convection formulæ, values are obtained for the coefficients which agree closely with those actually found in practice.

This latest contribution from the Department of Fuel and Gas Engineering is a good illustration of one phase of the work carried on by them. In addition to formal instruction, both in the classroom and in field work, the Department undertakes original investigations, and also endeavours wherever possible to apply to industry the results of research by other investigators, when these investigators have neglected to do so. Hottel's work falls under this last heading.

The original investigations of the Department are made both in the laboratory and on full-scale apparatus in the field. Research is now being carried out in the laboratory on rates of flame propagation in gaseous mixtures, hydrogenation of coal, synthesis of hydrocarbons, reactions in gas producers and water-gas generators, and on a number of other subjects.

In the various field stations located at plants of the Bethlehem Steel Company, Iroquois Gas Corporation, Cambridge Gas Light Company, and the Tide Water Oil Company, studies of a number of plant operations are being made. These include such subjects as heat transfer in regenerators, steam decomposition in water-gas generators, and efficiency and operating characteristics of crude petroleum stills.

THE PRESIDENTIAL ADDRESS

OF

JOHN WILKINSON, O.B.E.,

Engineer and Manager of the Nottingham Corporation Gas Department.

A year ago, your Council considered it advisable, in consequence of the stoppage in the coal industry, to cancel the arrangements which had been made to hold the annual general meeting, as usual, in the month of June. The meeting was eventually held in September; but even then the stoppage was still in progress, and it was not until the end of November, after a struggle extending over a record period of seven months, that peace was proclaimed.

There are many people—and I confess to being one of them—who would prefer that the miserable business should be entirely obliterated from memory. Unfortunately this is impossible, and, moreover, it would be unwise to close our eyes to certain important factors brought into prominence by the long suspension of mining operations.

MAINTAINING GAS SUPPLIES DURING THE COAL STRIKE.

Foremost is the fact of our industry having maintained an adequate supply of gas for all purposes throughout the full period of the stoppage. The effect of this on the welfare of the public and industry generally has been dealt with in speeches made by the chairmen of many gas undertakings, and also by information published in the Technical Press. It is not necessary, therefore, for me to occupy your time by repeating what has already been said on this phase of the position; but this is an opportune time to call attention to the heavy responsibility and strain thrown upon gas engineers during the unprecedented circumstances, and to acknowledge the able assistance given by our staffs and workmen who, in spite of the irritating actions of certain outsiders, remained loyal to their leaders and the industry.

The men were undoubtedly advised wisely by their leaders, and I am of the opinion that the decisions of our Joint Industrial Council with regard to wages and other matters, during the last ten years or so, were largely responsible for the attitude adopted. In any case, there are clear indications that the policy of the employers' side of the Joint Industrial Council never to attempt to enforce unfair wages or conditions of service is now appreciated by the other side. There may have been times when some of us have thought that our members of the Joint Industrial Council were offering a little too much to obtain a peaceable settlement of matters at issue; but one is never far wrong when giving the benefit of any doubt to the more needy party.

WHAT IS A SAFE COAL STOCK?

Secondly, our ideas with regard to the so-called safety stock of coal have received a rude awakening. Many of us have felt comfortable when carrying a stock equal to three months' maximum requirement. But who can now say what is an absolutely safe stock to provide? There is an economic side to the question, and, therefore, a limit to the stock we can carry without bringing into effect a visible increase in the price of gas. Hence it would appear that we must still continue to take risks, and be prepared to bear the strain of any prolonged stoppage in the coal industry which may occur in the future. A very useful auxiliary will be a suitable carburetted water gas plant provided with adequate oil storage.

There is the possibility of common-sense and considered judgment of economic circumstances carrying more weight in the future than has been the case in the past, but I am not at all sure that large combines of industries on the one side and of trade unions on the other are going to be conducive to such a position. The slogan "Unity is Strength" appears to be so easily construed into "Might is Right."

SEASONAL CONDITIONS IN THE COAL INDUSTRY.

Thirdly, the gas industry, using, as it does, such a large quantity of coal as raw material, must always be interested in the economic status of both mine-worker and colliery proprietor. If the former is unable to earn a living wage over the whole of the year, it is impossible to have peace and contentment in the coal industry. I have lived in close touch with mine-workers for many years, and, in my judgment, the chief cause of their discontent, which comes to the surface from time to time, is their inability to earn full wages during the summer months.

A temporary reduction in income of 20 p.ct. to 40 p.ct. is not conducive to contentment in any section of the community; and it is so easy at these times to make adverse comparisons with the wages paid in certain sheltered trades that there can be no surprise when agitators take advantage of such circumstances to make matters even worse than they need be.

It is obvious that the climatic conditions of the world generally control the use of fuel according to the seasons; and the suggestion is frequently put forward that the position should be met by industrial and domestic consumers stocking coal during the summer for use in the winter. This, however, can only be done to a limited extent, seeing that in many cases it is impossible in existing circumstances, and that additional storage facilities are not always available. Colliery proprietors have occasionally compelled gas undertakings to take their supplies of coal in equal monthly quantities throughout the year; but this procedure has done no more than touch the fringe of the problem.

It may not be possible to eliminate short time in seasonal trades, but it is surely not impossible to devise some means whereby the burden on the mine-workers can be eased when summer comes along. It seems to me that a start might be made by arranging a longer working day during the winter months and a correspondingly shorter working day during the summer months, with adjustments of the basic rates of pay to meet the varying conditions.

The adoption of the suggestion that recruiting of new labour for service in the coal industry should be suspended for a period would also be a step in the right direction.

Every fair-minded man is desirous that the mine-workers shall work reasonable hours and receive a wage sufficient to enable them and their families to live under comfortable conditions; but it has often been stated, and probably with a good deal of truth, that high basic wages are conducive to men taking holidays when there is plenty of work available. Statistics upon this important matter of wages have been published on many occasions in the past, but they have been generally stated in such a way as to be anything but easy to understand by those not engaged in the coal industry, and their accuracy has invariably been challenged by the mine-workers themselves. Surely it is possible to publish simple and clear statements which would enable the public to judge fairly whether the men are actually given an opportunity to earn reasonable aggregate wages over a full year. It is the day workers who suffer most.

COAL PRICES AND THE GAS INDUSTRY.

It is also equally important that the colliery proprietors should be assured of a fair return on the capital invested in the industry; otherwise development of new seams and collieries will not take place. This brings us to the all-important matter of price.

We are aware that management and other matters—of which only colliery proprietors and managers can speak with authority—play an important part in the question of price; and I will refer, therefore, solely to the suggestion, which is so often put forward, that gas undertakings do not pay an economic price for their requirements of coal. I have been purchasing gas coal for the past 35 years; and I heard this story for the first time when I negotiated my first contract. I heard it for the last time when I negotiated my last contract, *plus* a little extra colouring to the effect that there never will be a

contented coal industry until the gas industry is prepared to pay higher prices.

A little bluff in business is natural, and, so long as it is kept within reasonable limits, one can get a certain amount of enjoyment out of the game; but any deliberate attempt to increase permanently the price of the raw material utilized by an important industry should receive careful attention.

The gas industry, like other industries, must expect to pay an economic price for coal; but those responsible for the control of the industry should, in my opinion, resist any attempt to force the dictum that, as gas has so largely displaced coal for domestic purposes, the price of gas coal must be increased proportionately to the loss sustained by the coal industry in consequence of the reduced trade for house coal.

Assuming that the management is efficient—and I feel sure that the British colliery manager knows his job—the success of the coal industry depends mainly upon the average price realized for all grades of coal. It is also equally certain that a considerable tonnage of so-called slack is sold at prices much below the actual cost of production; and I suggest that colliery proprietors should, before seeking to impose a permanent increase in the price of gas coal, compare the calorific values of their respective productions of slack and gas coal and the actual prices realized over a series of years for the two grades of fuel.

Conversion of Solid Fuel.

Chemistry teaches us that matter is indestructible, but may change its form. In every-day life, however, many of us are apt to think, and sometimes to say, that everything must have a beginning and an end. Consequently, change in the structure or form of a certain commodity may possibly be taken as the end of the old and the beginning of the new.

Seeing, therefore, that the electrical industry—as it exists generally in this country—is employed like the gas industry in transforming solid fuel into an invisible form of energy capable of being transmitted through mains for the purpose of providing the community with light, heat, and power, we need not feel alarmed when we occasionally hear the opinion expressed that the gas industry—after a life of 110 years—has had its day, and will now fade out of existence.

Time only will prove the accuracy or otherwise of this opinion, but no harm can be done by taking stock of the present position and preparing our plans for the future as wisely as is possible with the engineering and chemical knowledge at our command. At the same time we must bear in mind the important factors incidental to present-day practice represented by the production of residual products in the form of coke, tar, and ammonia by the gas industry and the utilization of waste heat from blast furnaces and other sources by the electricity industry. I will refer later to gas produced at coke ovens.

Our industry was formed originally for the production of gas for lighting purposes; and, seeing that it has progressed continuously by reason of the extension of the use of gas for heating and power purposes, together with the increasing usefulness in many directions of coke, tar, and ammonia, it is not surprising that coal still remains the raw material upon which our operations mainly depend. On the other hand, we must, I think, admit that there is a certain strangeness in the fact that there has also been no radical change in our method of dealing with the raw material. Murdoch started the industry 110 years ago by carbonizing coal in a closed vessel, and we do the same to-day.

In these circumstances there would appear to have been some justification for the remark made a year or so ago by one of the most eminent of our colleagues to the effect that we did not understand the carbonization of coal.

I am sure our colleague will not require any apology from me for making use of the statement in question for the purpose of this address, because we realize that the carbonization of coal has been the mainspring of the gas industry since its inception, and will probably remain so for many years to come. If, therefore, the industry has attained its present position without those in control having had complete knowledge of their chief task, it is obvious that there are prospects of a brilliant future when we learn to understand our job thoroughly. Let us see how far we have actually advanced, and what are the prospects for the future.

Progress in Efficiency.

In the records of the Nottingham gas undertaking for the year 1819 there appears a statement that the average make of gas per ton of coal carbonized was 8015 c.ft. There is no mention of quality, but it may be safely assumed that it was a rich gas having a calorific value possibly as high as 700 B.Th.U. (gross) per c.ft., equal to 56·1 therms per ton of coal.

This yield was obtained by the use of cast-iron retorts, and is comparable with the present-day figure of 72 therms of straight coal gas per ton of coal obtained by carbonizing a probably similar coal in horizontal fireclay retorts—the first of which, it may be mentioned incidentally, was introduced into the Nottingham Gas-Works in the year 1823.

The above figures represent a total increased thermal efficiency of 28·34 p.ct., or 0·26 p.ct. only on the original figure for each of the 107 years which have since elapsed. This increase has the appearance of being very small, but it would have been smaller still had the old standard of quality—illuminating power—remained in operation; and too much praise cannot be given to those responsible for the change from illuminating power to calorific value as the recognized standard of quality, which change undoubtedly opened the way to further development in the production of energy in the form of gas.

It is apparent that the process of gas-making, as instituted by Murdoch, was capable of attaining a reasonable standard of efficiency; and one is tempted to compare the respective total thermal efficiencies obtained from a ton of coal by the oldest type of gas plant and the most modern form of electric generating plant. Clearly gas obtained much the better start, but we shall be acting wisely if we prepare our future work in the gas industry on the assumption that within the present-day weakness of the sister industry lies its future strength.

Three Questions.

I will refrain from making any detailed comparisons between the respective total thermal efficiencies which are now obtained by the gas and electrical industries; but comparison of the figures regarding the gas industry over the past 107 years forces upon me the following questions:

(*a*) Is the increase in gaseous thermal efficiency satisfactory?
(*b*) How has it been attained?
(*c*) Can it be improved?

With regard to (*a*), I confess a desire to sit on the fence in a position to face either way, because I think the position is parallel to the schoolboy and the snowball which he rolls until its size and weight have increased beyond his power, and he has, perforce, to retire from the conflict or obtain outside assistance. He may, or may not, be satisfied with his efforts, according to his temperament, and it seems to me that many of us are in much the same position with our horizontal retorts.

A more positive answer can be given to (*b*), because it must be admitted that the increased efficiency is due directly to carbonizing the coal at higher heats. I realize that there are certain side issues involved, but the main factor has been the simple application of higher heats to the charge of coal inside the retort, and the higher thermal yield has been obtained by the permanent gasification of a portion of the tar.

Dealing now with (*c*), we are aware that each ton of coal carbonized in a horizontal retort still produces from 10 to 12 gallons of tar, which can be treated, more or less successfully according to the character of the plant employed, for the production of permanent gas.

It is probable that part of this conversion could be obtained in the retort itself by carbonizing the coal at still higher heats, or arranging for the crude gas, after it has been given off from the coal, to come into contact with certain substances heated to a sufficiently high temperature to gasify permanently a portion of the tar. It may be also that the improvement in the quality of refractory materials will continue, or that some form of metal capable of a long life in the form of a retort working at an abnormally high heat will become available at a reasonable cost. There is, however, an economic limit to the

heat at which coal can be carbonized in horizontal retorts for purely gas-making purposes, and experience has proved that it is not always wise to do too much in the way of utilizing the retort for cracking purposes; hence I am of the opinion that the tar will eventually be dealt with in ancillary plant if it is proved that its permanent gasification is a profitable operation, provision being made to prevent waste of the free carbon.

We have also left to us the possibility of outside assistance referred to in my answer to question (*a*)—such as introducing into the retort some agent which would promote the combination of hydrogen with carbon (coke).

It has been in our favour that the present standard of efficiency in the production of straight coal gas has been obtained by the use of a fairly simple and direct process which could be worked at a reasonable cost; and one feels inclined to express the opinion that the chances of introducing catalytic processes inside the retort for the purpose of increasing the thermal yield of gas on a commercial basis are somewhat remote.

Probably many of you are wondering why I have referred so far only to the horizontal retort. The explanation is that I have been tracing the development of the production of straight coal gas for town supply; and the horizontal retort is still, in my judgment, the best form of plant for that particular purpose.

Fortunately, it is not now absolutely necessary to make straight coal gas for town supply, and we are entitled to claim any increase of thermal efficiency obtained as the result of indirect methods such as steaming the charge in a vertical retort.

The mention of vertical retorts opens the way—if one is inclined to take it—to abnormally high thermal yields and, indeed, to total gasification. But I have in mind financial results and other factors which prompt me to refrain from putting before you any figures relating to the production of gas of a calorific value less than 475 B.Th.U. (gross).

I do not desire either to attack or defend the standard of 475 B.Th.U., but it appeals to me as a fair figure to adopt for the purpose of comparison. In any case, it enables me to put before you a yield of 80 therms per ton of coal carbonized.

It will be seen that the additional 8 therms obtained by the use of vertical retorts enables us to claim a total increased thermal yield of gas equal to 42·6 p.ct.; and, even if this should prove to be the maximum economic limit, it provides substantial security for the future of the industry.

Residuals—Coke.

Efficient carbonization of coal does not, however, begin and end with the production of gas. Coke is almost equally important, and tar products are by no means negligible. As a matter of fact, the industry has been able to recover from the sale of residual products more than half the cost of the coal carbonized. But there are indications that the residual products will be up against much keener competition in the future than has been the case in the past.

It may be said that up to the present the gas industry has supplied all the coke used for domestic purposes, and also a substantial quantity for various industrial purposes; but the managers of coke ovens, which hitherto have produced a dense hard coke suitable only for blast furnaces, foundry work, and similar purposes, are now turning their attention to the manufacture of coke somewhat similar in character to that produced in gas-works, and it is admitted that a number of gas undertakings experienced considerable loss of business in competition with oven coke during the latter half of 1925 and the early part of 1926. During this particular period the demand for oven coke from the usual sources was much reduced, and the price exceptionally low. Hence enterprising coke oven managers made their first real attempt to capture a portion of the gas coke trade.

One important factor would appear to be the probability that competition from oven coke will always be most severe when the heavy industries—iron and steel—are experiencing a slump in trade; and, as there cannot be general prosperity in other industries in such circumstances, the low prices for coke will come at inopportune times. During such periods we shall probably obtain some assistance from lower prices for coal, but the least we ought to do in an endeavour to retain the existing gas coke trade is to send out coke of good quality and as free from ash and moisture as circumstances will allow. Much can be done to produce a free-burning coke; and the temptation to over-quench should be resisted.

I will not take up too much of your time with a subject so thoroughly understood by all gas engineers, but I desire to take the opportunity to refer briefly to the growing preference of the general public for coke made in vertical retorts. In my experience carbonizing coal in horizontal retorts at higher heats has generally produced complaints from consumers of coke for domestic purposes, and I am of opinion that such complaints were justified from the point of view of the customer, seeing that the coke appeared to be more dense in structure and contained less volatile matter. On the other hand, we know that coke produced in vertical retorts does not contain more volatile matter than coke produced in horizontal retorts worked at high heats, and it is apparent that the public appreciate the fact that coke produced in vertical retorts burns more freely, and generally contains much less moisture.

Tar.

Turning now to the question of tar, we realize that any development of the coke oven industry, or other methods of carbonizing coal at the pit head, will result in more tar being put on the market, and consequently keener competition for business. Nor can we overlook the fact that bitumen compounds for making and dressing our highways have come to stay. Therefore, as with coke, so must it be with tar—viz., it is essential to give the road authorities the article they desire. This subject is receiving the close attention of all parties interested in the production of coal tar; and progress is being made in the compilation of specifications for prepared coal tar, which, it is hoped, will be suitable for the various purposes to which it is applied.

I presume that all of you have, like myself, read with great interest the papers presented at the Tar Symposium held at Manchester in November last, and have noted with considerable alarm the suspicion attached to vertical retort tar, in respect not only of road making and dressing, but also of the pitch produced therefrom if it is to be used as the binder in the manufacture of briquettes.

The troubles referred to in certain of the papers are not entirely unknown to the undertaking with which I am connected; and the desirability of instituting special research on vertical retort tar has been brought before the notice of your Council and also the National Gas Council. It is obvious that specifications intended to apply to horizontal retort tar and its products are not applicable to vertical retort tar and its products. Hence some change is necessary if gas undertakings are to be placed in the position of being able to supply, at prompt notice, prepared tar suitable for the purpose to which it is to be put.

I quote as a simple example the fact that vertical and horizontal retort tars of similar specific gravity give very different results when tested for consistency; and as the latter is the factor which really affects the road makers, it does not seem advisable to load specifications with a test which is not actually necessary.

It would be of material advantage to many gas undertakings to be able to produce a straight-run prepared tar; and I am far from being satisfied that it is always necessary to specify a maximum of 3 p.ct. of tar acids at boiling-points under 270° C. A very large proportion of the prepared tar is used on roads which are far removed from fishing streams.

There is no desire to deny the fact that vertical retort tar contains a high percentage of acids; and, as the use of vertical retorts is increasing year by year, it seems reasonable to suggest that research work on coal tar for road making and other purposes should be directed mainly to vertical retort tar. My remarks with regard to research and the amendment of specifications are also applicable to creosote produced from vertical retort tar. Creosote is used in large quantities as a wood preservative; and there is considerable difference of opinion among chemists as to the suitability of vertical retort creosote for such purpose.

It will be contrary to my intention if these remarks are construed into a suggestion that an attempt should

be made to force unsuitable material upon our customers, but it is my opinion that we should endeavour to clear up the doubt as to whether certain tar acids are beneficial or otherwise, as wood preservatives. It should not be overlooked that the characteristics of the acids obtained respectively from vertical retort and horizontal retort tars are dissimilar; and my desire is to prevent mere prejudice from adversely affecting the value of vertical retort tar. The development which has taken place during recent years in the matter of co-operative tar distillation is a step in the right direction, and these schemes will probably extend when plants at present serving a useful purpose in medium sized gas-works become worn-out. Naturally, a good deal will depend upon the terms offered by the co-operators.

Sulphate of Ammonia.

So far as sulphate of ammonia is concerned there does not appear to be anything new to be said. Prices are low, and the margin between profit and loss is now very narrow in the case of small undertakings. The prospects of reduction in working costs are controlled mainly by the price at which supplies of sulphuric acid will be available; but I do not see that the present margin of profit obtained by the acid manufacturers will allow of any substantial reduction in price. There is, however, the possibility of utilizing gypsum as a substitute for sulphuric acid, as in the case of sulphate produced from synthetic ammonia.

The manufacture of synthetic ammonia has undoubtedly had a serious effect on the prices of sulphate of ammonia and nitrate of soda, and it appears certain that the future prices of the latter commodities will be controlled by the price at which synthetic ammonia can be produced. Probably this was the chief reason why the British Sulphate of Ammonia Federation, Ltd., decided to appoint Nitram, Ltd., as their sole propaganda and selling agents until 1946; and we must hope that time will prove this arrangement to have been in the interests of all makers of sulphate.

Disposal of Effluent.

In addition to the loss of revenue due to the lower prices realized for sulphate, certain undertakings are having to face increased costs in respect of the disposal of the effluent from their plants; and this trouble, which is by no means new, appears likely to increase.

The National Gas Council had this matter under consideration some months ago, and decided to request our Institution to appoint a Special Committee to investigate the position. This Committee was formed without delay, and special research work is now proceeding, but the problems to be solved are so complex that the evolution of a satisfactory method of treatment may not be forthcoming as early as some of us desire. Our immediate Past-President, Mr. Botley, is Chairman of the Special Committee, which is working in close collaboration with the research department of the Leeds University and the engineers of those works where experiments are being carried out on a practical basis, and we may rest assured that every effort will be made to devise a method which will be efficient and not too costly to operate.

I have now come to the end of my brief remarks on the main factors involved in the carbonization of coal in gas-works; but any statement on the carbonization of coal is probably incomplete unless reference is made to low-temperature carbonization and coke ovens.

The gas industry is undoubtedly interested in both these processes, and gas engineers have been carefully watching, and will continue to watch, for opportunities to make use of either or both of them on a commercial basis.

Low-Temperature Carbonization.

Low-temperature processes have sprung up in all directions like mushrooms, but careful investigation as to their utility in the gas industry has always revealed a negative result. What the future may hold in store no one can say—oil may prove eventually to be the deciding factor—but there is no low-temperature process in operation at the present time which can give the same financial results to the gas industry as the modern carbonizing plant used in gas-works. This is the only reason why low-temperature processes have not been adopted up to the present in gas-works; and I do not intend to make any further comment upon this subject except to take the opportunity to express appreciation of the reports which are issued from time to time by the Fuel Research Board. These reports clearly state the results of tests carried out by independent experts, and vindicate the gas industry from any suspicion that attempts have been made to stifle a rival industry.

Gas from Coke Ovens.

The position with regard to coke ovens is very different, and to my own knowledge gas from coke ovens has been utilized for town supply for more than twenty years past. I am aware that up to a few years ago this was done on so small a scale as to be practically negligible, but it does show that gas engineers are not slow to take advantage of anything worth having.

Colonel Stephenson, Chairman of the Sheffield United Gas Company, in a recent speech to the shareholders of his Company, referred to coke oven gas, and expressed the strong opinion that its potentialities, as regards the general gas supply of the country, have not received the attention they deserve. I submit, however, with great respect, that the gas industry is not to blame for this.

In the early days of coke ovens the gas produced varied in quality from hour to hour, and in the few cases where such gas was utilized for town supply numerous complaints were received from the consumers. I well remember the description—wind and sparks—which was inspired by actual experience of the consumers in the area of a small gas undertaking in Yorkshire which had utilized coke oven gas for town supply.

Efforts were made to induce coke oven managers to work the ovens so as to give a more regular quality of gas, but they were, at that time, much more interested in the production of coke, tar products, and sulphate of ammonia than in the production of gas. A fairly long period elapsed before they realized that it was worth their while to give special consideration to the production of gas suitable in quality for town supply, and the position was eased very materially when the change from illuminating power to calorific value took place.

There were then differences of opinion as to what was a fair price for coke oven gas; and it was not an easy matter to convince the coke oven managers that the difference between the price offered for their gas and the actual price received from the consumer did not represent an exorbitant profit to the gas undertaking. I also have a distinct recollection of the Sheffield Gas Company itself obtaining a net revenue from the sales of residual products more than sufficient to meet the total cost of coal carbonized; and it is obvious that in those days the Directors could not afford to pay 6d., or even 3d., per 1000 c.ft. for coke oven gas.

Circumstances have, however, changed since those days; and it is fitting that the Sheffield Company should be the first British undertaking to develop coke oven gas for town supply on a large scale. This Company has had the reputation for many years past of supplying gas to their consumers at exceedingly low prices; and apparently their latest development will enable them to maintain their much-coveted position in this respect. Local circumstances always play an important part in these matters, but due credit must be given to those who take advantage of opportunity.

I am not quite sure what Colonel Stephenson really had in mind when referring to the general gas supply of the country, but the South of England would appear to be outside the limits of any scheme for the utilization of surplus coke oven gas by the gas industry until the development of the Kent coalfields on a large scale has become an accomplished fact. This reduces the present field of operation by 50 p.ct., but there still remains a consumption of 135,000 million c.ft. per annum, and this affords ample opportunity in various districts to absorb the whole of the surplus coke oven gas, provided satisfactory terms can be arranged.

I agree entirely with the opinion that, if ever the surplus coke oven gas is to be fully utilized, it must be purchased and handled by the gas undertakings, who alone are in a position to deal with it efficiently in the best interests not only of gas consumers but also of fuel and power economy.

If the anticipated developments in the coal industry do actually take place, it is certain that there will be a large quantity of coke oven gas available to the gas industry

for town supply or to the electricity industry for the generation of electricity; and I am confident that those responsible for the administration of the gas industry in districts directly interested will always be prepared to offer fair terms to the owners of the coke ovens.

I notice that, according to information which has been obtained by Colonel Stephenson, the surplus gas is not worth more to the coke oven undertakings than 3d. per 1000 c.ft.; and it seems to me that a profit of 1½d. per 1000 c.ft., representing approximately 1s. per ton of slack carbonized, is well worth having. Be that as it may, a price of 4½d. per 1000 c.ft. would probably create a demand greater than the supply available.

Factors Other Than that of Price.

It must not be overlooked that there are other important factors besides that of price, and I have personally turned a deaf ear to schemes which have been submitted to me under which our carbonizing plant would be definitely closed down, and the whole supply of gas brought in from coke ovens. Such a position may become feasible in the future, but at present I am not prepared to place more than 50 p.ct. of my eggs in one basket. Continuity of supply and regularity of pressure and quality are essential to the well-being of gas undertakings individually and to the industry as a whole.

There are other factors which affect the position, and it is obvious to gas engineers that terms highly favourable to one undertaking may be just as unfavourable to another concern, even though they may be equal in size. Similarly, what may be good for America or Germany, may be useless for this country.

A point of considerable importance was recently raised by Mr. William Cash, Vice-Chairman of the National Gas Council—viz., In what position would a statutory gas undertaking supplying coke oven gas stand in the event of such supply failing? This is a matter which could easily be covered by legislation, but it shows the necessity for careful judgment before embarking on new schemes of gas supply.

National Fuel and Power Committee.

It may be well for me to remind you at this juncture that the Institution was invited by the National Fuel and Power Committee to present evidence on behalf of the gas industry. After discussing the position with the Executive Committee of the National Gas Council, a joint Committee was appointed to consider the lines upon which such evidence should be prepared, and to decide who should prepare and submit it, and undergo cross-examination thereon. Eventually it was decided to ask Mr. Thomas Hardie, Chief Engineer of the Gas Light and Coke Company, and Prof. J. W. Cobb, of Leeds University, to undertake the task; and, fortunately, both agreed to do so. A synopsis of the evidence has been published in the monthly reports issued by the National Gas Council, and in these circumstances I will content myself by saying that we are under a deep debt of gratitude to these gentlemen for their valuable work. The evidence dealt with every phase of our industry in such a comprehensive and clear manner that it could not fail to carry conviction that we are practising fuel economy to the utmost extent, and that town gas provides facilities for many other industries to do likewise.

Work at Leeds University.

Many of the well-known proverbs which have been handed down from generation to generation contain considerable wisdom; and the gas industry—despite its long existence—accepts the axiom that it is "never too late to mend or too old to learn." Hence we are constantly asking the Research Department at Leeds University to investigate complex problems which require elucidation in the interests of commercial efficiency. There is a wide difference between experimental work in the laboratory and the practical application of science to industry, but the reports submitted to these meetings year by year are indicative of the energy and judgment displayed by those responsible for the research work at Leeds University.

It is not always a congenial job to be engaged week by week or, may be, month by month attempting to catch the elusive will-o'-the-wisp. There are many disappointments before success is obtained in the laboratory, and the chemist has then to collaborate with the engineer for the purpose of adapting laboratory experiments to works practice. I am sure it is your desire that our appreciation of the work done at the Leeds University should be expressed at this meeting.

It is impossible to speak of the Leeds University without thinking of Prof. Smithells, who is always ready to emerge from his retirement and give the industry the benefit of his long scientific experience. He has done much to bring together the scientist and the engineer.

Refractory Materials.

We must also express our appreciation of the research work carried out under the auspices of the Refractory Materials Committee. A firebrick is a very ordinary looking article to the man in the street, but its importance is fully realized by those who are called upon to bear the responsibility of working processes which require the application of abnormally high heats. The failure of a single brick in a vital part of a costly plant may prove to be a serious matter; and we cannot afford to relax our efforts in assisting the manufacturers to produce refractory materials which are suitable in every way for the work for which they are required.

I have been privileged to attend several meetings of the Refractory Materials Committee, and I was much impressed with the difficult nature of the work upon which the Committee have embarked. If they are successful—and we trust that they will be—it will mean increased economy and efficiency in many important processes, including gas production.

Fuel Research.

I referred to the work of the Fuel Research Board in my brief reference to the subject of low-temperature carbonization; and an able writer could keep you fascinated for hours with the details of the work done on problems which affect—or may affect, directly or indirectly—the gas industry. A little overlapping in research work may take place, but that is not harmful. To neglect it is not only harmful, but absolutely dangerous.

I will now conclude my remarks upon works operations by expressing the opinion that, despite the progress we have made, it is impossible to give serious thought to certain processes, which are now receiving the attention of many brilliant chemists, without feeling somewhat uneasy as to whether it will have been definitely proved in twenty or thirty years' time that the gas engineers of to-day knew very little about carbonization—perhaps it may be better to say treatment—of coal for the production of town gas. If the coming generation can improve upon the present one, so much the better for the industry and the community generally, and it is only natural that this should be so. Mr. A. F. Bezant, Editor of the "Gas Journal," was right when, in his speech at the recent Jubilee Meeting of the North of England Gas Managers' Association, he advised those responsible for the control of the gas industry to "look forward." His suggestion that this Institution should form a special Committee, representative of all sides of the industry, to watch carefully all new processes for the carbonization or treatment of coal, whether evolved at home or abroad, is an admirable one; and he may rest assured that sight will not be lost of it.

The "N.G.C." and the "B.C.G.A."

During my period of office as President I have been one of your representatives on the respective Executive Committees of the National Gas Council and the British Commercial Gas Association; but circumstances have been such as to allow me to attend only the meetings of the former. No observations from me are, however, really necessary to emphasize the importance of the work carried out by both bodies; and we are aware that the work of either would provide suitable material for a very useful and instructive discussion covering a full day.

The National Gas Council has obtained a firm grip on all legislative and commercial problems appertaining to the industry, and much of the success achieved is due to the indefatigable services of the Chairman, Sir David Milne-Watson.

The Council's subsidiary body, the Federation of Gas Employers, has also rendered excellent service. The

goodwill of our workmen is essential to our prosperity, and I have already expressed the opinion that the fair-minded manner in which our representatives on the Joint Industrial Council have always approached questions of wages and conditions of service is now appreciated by the representatives of the men.

The work of the British Commercial Gas Association has been of considerable importance in the past, but it will probably attain more importance in the future.

The Government has passed the Electricity (Supply) Act, 1926, on the assumption that it is in the interests of progress; and we must accept it as such. But progress of the sister industry does not carry with it the beginning of the end of the older industry. There has been room for both up to the present; and there will be in the future, so long as the competition is fair, and each is compelled to provide for itself.

Overhead cables will undoubtedly enable electricians to supply many rural districts which are now without either gas or electricity. In many of these cases a supply of gas is commercially impossible, and the least we can do is to wish success to such schemes as are capable of conferring benefits on any section of the community. The gas industry has always trod the path of progress in the past; and we shall not attempt to block that path at any time in the future. We shall stand or fall in accordance with the merit of our own work.

SERVICE TO THE CONSUMER.

For fifty years or more it has been said that dividends are made in the retort house; and we shall never be able to relax our efforts in the works, no matter what new processes may be evolved. But if we put the same energy into the sales department in the future as we put into the works in the past, we shall be kept busy for many years to come.

We must concentrate on service to the consumer. Recent experiences have shown us clearly that the public appreciate the many uses to which gas is economically applicable; and with efficient propaganda, attentive service, and hard work, success is sure to follow. We must also take steps to eradicate all individual cases of neglect and indifference such as were mentioned at the recent conference arranged by the British Commercial Gas Association and the Institution. They are a menace to the industry and those working in it.

Service to the consumer leads up to our Education Scheme; but I have already occupied too much of your time, and I will content myself by expressing the sincere hope that all the difficulties which are being encountered will be speedily overcome, and that the strenuous work which Mr. Goodenough and his colleagues have put into the Scheme will eventually produce the right type of recruit.

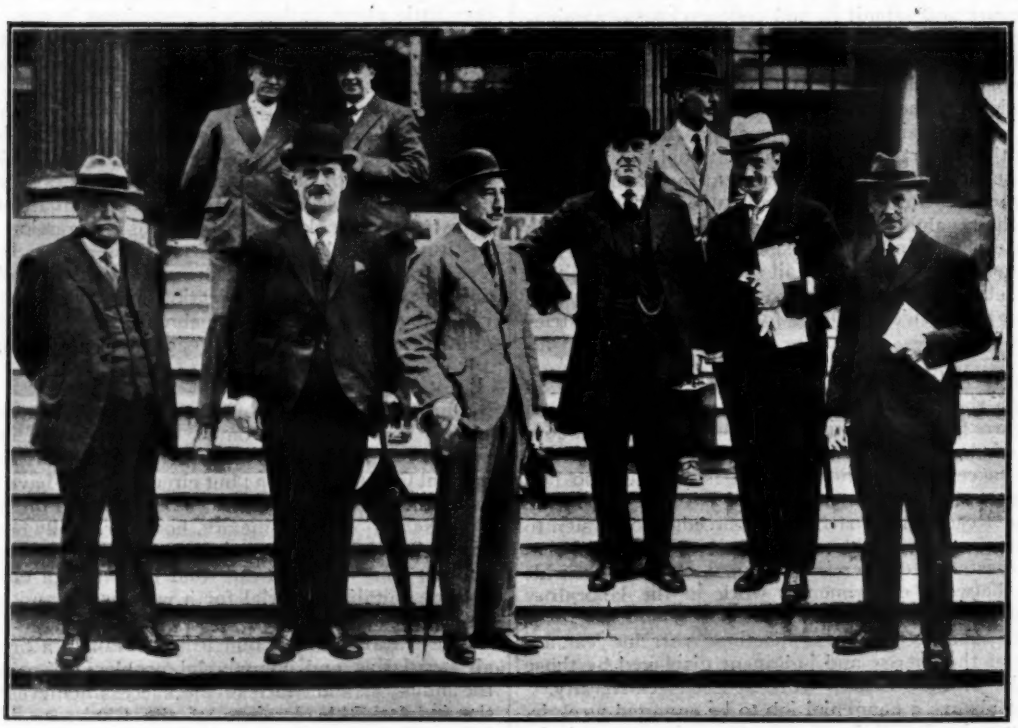
Last year the President, Mr. Botley, concluded an admirable address by suggesting our adoption of the inspiring motto contained in the following lines:

> To set the cause above renown;
> To love the game beyond the prize.

Such a motto will carry many men a long way on the path of success. But I have been through the mill, and have experienced the tension of waiting for the much-desired step upward which always seemed so far away. Some of my colleagues present here this morning are now going through the same mill—few miss it—and if this experience is really necessary to bring the best to the surface, we can find consolation, and inspiration, in these words of Milton:

> They also serve, who only stand and wait.

THE PRESIDENT, VICE-PRESIDENTS, AND OTHERS.



From left to right: Mr. W. Collin (Bridgend), Mr. J. H. Canning (Newport, Mon.), Mr. H. D. Madden (Cardiff), Mr. John Wilkinson, O.B.E. (President), Mr. J. W. McLusky (Glasgow), and Mr. John Terrace (London).

GENERAL REPORT OF THE PROCEEDINGS.

THE PRESIDENT, JOHN WILKINSON, ESQ., O.B.E., IN THE CHAIR.

[The Address, Papers, and Reports referred to will be found on pages following this report.]

The PRESIDENT (who was received with loud applause), on opening the proceedings, said: Gentlemen, there are no shadows of strikes this year to overcast our proceedings, so I take the opportunity to wish you a cheery "Good morning."

Confirmation of Minutes.

The PRESIDENT: The first business is the confirmation of the minutes of the last annual general meeting. I will formally move that they be taken as read, and confirmed.

This was agreed to.

Appointment of Scrutineers.

The PRESIDENT: I understand that Mr. C. Valon Bennett (Rochester) and Mr. C. M. D. Belton (Shrewsbury) have offered their services as Scrutineers for the examination of the balloting lists for the election of officers and Council for the year 1927-28.

Their appointment was unanimously agreed to.

H. E. Jones "London" Gold Medal.

The PRESIDENT, calling to the platform Mr. C. H. Rutter, M.Inst.C.E., of Brighton, said: Mr. Rutter, by a ballot vote of the Council, the paper which you were good

C. H. RUTTER, M.Inst.C.E.
Recipient of the "London" Gold Medal.

enough to read before this Institution last year on "The Development and Reconstruction of the Portslade (Brighton) Gas-Works" was awarded the premier position. I am quite sure that, when you sat down to prepare the paper, the thought of any award never entered your mind; but, at the same time, you would not be the man we all know you to be if you did not feel considerable pride at the fact that your fellow-members have seen fit to honour you by awarding you the H. E. Jones "London" Gold Medal. May the sight of this medal in future years bring back to your mind recollections of the happy times you have spent with your colleagues in the gas profession. [Applause.]

Mr. C. H. RUTTER: It is indeed a great honour to receive this medal; and I thank the President for the kind words he has made use of in presenting it to me. I look upon the late Mr. H. E. Jones as one of my professional godfathers. He supported my application for admission as an associate member of the Institution of Civil Engineers, and also my transference to full membership. He was always interested in the Portslade Works, which he on many occasions visited; and he was particularly interested in the coal conveying plant that I had the honour of describing in the paper. So I feel sure that, could our dear friend have been with us now, he would have appreciated this presentation, for the sake of old acquaintance. I can only again express my very sincere thanks to the Council of the Institution, who have awarded me this medal, which I shall regard all my life as a token of a kind presentation, and as a great honour to hold. Really, I feel that my paper, although the discussion proved so interesting, was in itself rather mediocre.

The Diplomas.

The PRESIDENT: I now have to present on your behalf the Diplomas in Gas Engineering awarded as the result of the last examination by the Institution. They are as follows:

First Class, with Distinction.

Mr. Henry Preston Lupton, B.Sc., Liverpool.

Second Class.

Mr. John Walton Pallister, Assoc.M.Inst.C.E., Middlesbrough Corporation Gas Department.

Mr. Edward Morgan Edwards, Holyhead and North Wales Gas and Water Corporation.

Mr. Lupton, I am sure you must feel highly gratified at the fact that you have been able to obtain not only a First-Class Diploma, but also the award of distinction. It will prove, I trust, the forerunner to a highly successful career in the profession which you have chosen. May good fortune attend you throughout the whole of your career. Mr. Pallister, I sincerely trust that you do not feel any little disappointment at the fact that you did not secure a First-Class Diploma; but if you do, I would remind you that, whilst speed may win the 100 yards sprint, it is general fitness and determination which carry a man through in the 10 mile race. I wish you every success in your future career. Mr. Edwards, I find that you also have obtained a Second-Class Diploma; but I see also that you have received your training in a small works. Well, I am not ashamed to tell you that I am the product of a village gas-works, even smaller than the one with which you have been associated. I think it is necessary for you and all the young men of the profession to bear in mind that the members of this Institution are always ready and willing to pull a man up, but never to thrust him down. You have my best wishes.

New Honorary Members.

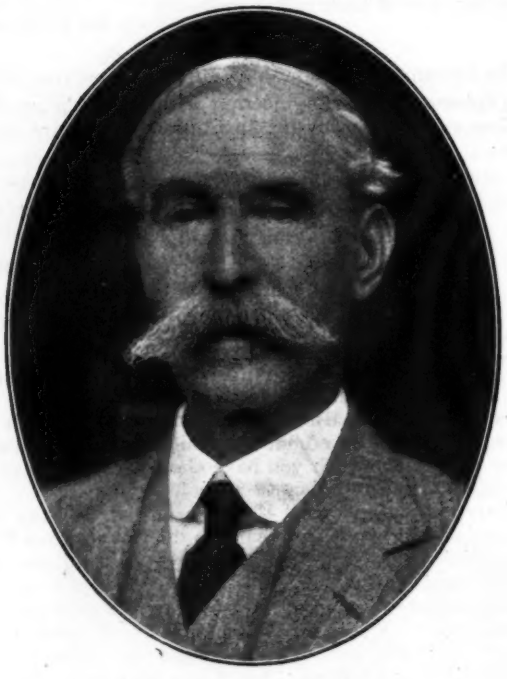
The PRESIDENT: May I ask you to approve the nomination as honorary members of the Institution of the respective Presidents of various Associations across the waters? They are the Presidents of the American, Belgian, Canadian, French, German, Italian, Norwegian, Swedish, and Swiss Gas Associations. The French Society has been divided into two sections. I presume it is your wish that both sections should be treated alike.

This was agreed to.

Mr. John F. Simmance.

The PRESIDENT: Elections to honorary membership of our Institution are few and far between; and there are good reasons why this is so. But it is now my pleasing duty to ask you to honour a veteran who has given over 50 years' service to the study, invention, and construction of scientific apparatus which is in every-day use in gas-

works, iron and steel works, and many other industries where large quantities of fuel are used. I refer to Mr. John Frederick Simmance. Some of our members are of the opinion that more use should be made of our powers to elect honorary members; but, be that as it may, I am confident no one will doubt the wisdom of our Council in bringing before your notice the name of Mr. Simmance. I cannot claim personal acquaintance with him; but I have been long acquainted, like all others present, with apparatus of various kinds which are the result of his inventive brain and skilful craftsmanship. Mr. Simmance became a pupil of the late William Sugg in the year 1875, and since then has been engaged continuously in inventing and constructing various forms of apparatus and instruments, some of which have proved quite capable of inflicting torture upon gas engineers—at inopportune times—as well as giving them assistance. Indeed, I am informed that one of his last pieces of work is the design and construction of a standard street photometer which is used for penalizing tests by the Westminster City Authorities. In such circumstances, it seems to me to be absolutely necessary to enrol Mr. Simmance among the honorary members. I always think it is wise to be on good terms with those who are interested in the infliction



JOHN F. SIMMANCE, M.Inst.C.E.
Elected an Honorary Member.

of penalties. [Laughter.] To be serious, however, we must all appreciate the valuable assistance which Mr. Simmance has rendered to the gas industry by the provision of testing appliances which have enabled us to carry out certain branches of our work on scientific lines, thereby producing better results from our raw material—coal—and at the same time giving greater satisfaction to our consumers by securing regular quality. Photometers and calorimeters are to Mr. Simmance what clay is to the skilled potter; but many other forms of scientific apparatus have received his attention. I need only remind you of his recording "gravitometer," which was used during the war by the British, French, and American Aircraft Departments for the purpose of recording automatically the lifting capacity of lighter-than-air flying craft. Mr. Simmance has been a member of at least one Parliamentary Committee appointed to consider photometry. He has given expert evidence on many occasions on behalf of gas undertakings. He is a member of the Institution of Civil Engineers and of the Institution of Mechanical Engineers. His work is well known to all our members; and I now formally move, in accordance with the unanimous vote of the Council: "That Mr. John Frederick Simmance be elected an honorary member of the Institution of Gas Engineers."

The resolution having been put to the meeting, and carried with applause,

Mr. JOHN F. SIMMANCE said: I do not really know what I can reply to all the kind remarks the President has made, and to your unanimous vote. It is about as overwhelming a situation as I have ever known. Certainly, it is the greatest honour I have ever received. What you have heard from the President is a sort of record of my misdeeds. [Laughter.] I do not think that your ordinary members can possibly quite understand what an honorary member feels. You have fallen into your membership almost automatically, as a matter of course. But it is a very different thing for anyone who at one moment is not a member, and then at the next moment is. It always seems to me that the man who is born to the Peerage cannot think as much of the honour as the man who has it conferred upon him later in life. It is a great gratification to me to be made an honorary member of the Institution; and I can say no more than that I thank you from the bottom of my heart.

An Invitation to Nottingham.

Sir ALBERT BALL, J.P. (Chairman of the Nottingham Corporation Gas Committee): I feel somewhat nervous in my exalted position here to-day; but I am proud to support your President. I am not going to attempt to make a speech; but I do wish to congratulate the Institution of Gas Engineers upon the selection of their President for this year. Mr. Wilkinson has made an excellent President, as he has always made an excellent gas engineer. And while congratulating you upon the selection of your President, I also congratulate myself, because fifteen years ago it was my pleasure to interview Mr. John Wilkinson, your President, and to give him the appointment which he holds to-day. We have never had a more capable Gas Engineer in the City of Nottingham than we have to-day; and I sincerely hope that he may be spared for many years to continue his work and to be of great service to this Institution, of which he is so proud to be the President. However, I have not risen to throw bouquets to your President, but to give you all, and your friends, a very hearty invitation to visit our old City of Nottingham. There are, I am sure, very few members present who do not know Nottingham, because if you have not visited it in your older days, most of you will have done so in your youth, to see the pretty girls we have there, if for no other purpose. [Laughter.] But we hope to show you something of the more serious side of Nottingham, as well as its beauties. We want you to come and see undertakings that are doing useful work in the development of industry. We will give you a hearty welcome at lunch, and then you shall see in the surrounding district some of what are undoubtedly among the most beautiful spots in the country. My Committee and I sincerely hope that as many as possible will take part in the visit.

The PRESIDENT: On behalf of the members, I thank you, Sir Albert Ball, for your kind invitation. ["Hear, hear."]

The President's Address.

The PRESIDENT then proceeded to deliver his address; and at its conclusion,

Mr. W. DOIG GIBB (London) said: It gives me the greatest pleasure to propose that the best thanks of the Institution be given to our President for the very able address which he has just delivered. It gives me the greater satisfaction to do so, because we are old friends, and have taken part together in pleasure and in the discussion of various technical matters. He is strenuous and thorough in all that he does; and when he received the highest honour which the Institution can confer, I felt quite certain that he was more than equal to his task, and would fulfil it in his usual determined Yorkshire fashion. We have heard the address; and we must all, I am sure, be aware that it has given us quite a lot to think about. We certainly appreciate it. What he has said about the coal question must have made a deep impression upon all of us; and we can only hope that something will result from his broad-minded views. It is not permissible to discuss the

Presidential Address, because tradition is against it. I say "tradition" rather than "precedent," because we are all thoroughly sick of the word "precedent." It does seem to me that if Parliament, the Board of Trade, and other highly-placed bodies would dismiss the bogey of precedent from their minds, it would be better for the nation, and help it to progress more quickly. But even if we were allowed to criticize the Presidential Address, I think there is very little criticism or argument that could arise. We all appreciate that it is an address from an enlightened and far-seeing mind. The President's summing-up of present-day conditions and the many problems which affect the interests of the gas industry has been admirable. I have therefore the utmost pleasure in proposing a hearty vote of thanks to him.

Mr. THOMAS GLOVER (Norwich): I am delighted to second the vote which has been so ably proposed by Mr. Doig Gibb. I have heard many reviews of the industry by Presidents of the Institution. I do not remember one which has been prepared so well or from such a practical standpoint as that to which we have listened this morning. There are two particular sentences in the address which I commend to you: "The gas industry has always trod the path of progress in the past; and we shall not attempt to block that path at any time in the future. We shall stand or fall in accordance with the merit of our own work." ["Hear, hear."] I was very glad to note the hearty applause at the close of the address; for the President did not give us much chance of applauding during its delivery. Mr. Wilkinson is to be congratulated, not only upon having prepared such an address, but also upon having read it to us so clearly. We thank him for this fine review of the affairs of the industry, and for the spirit of hope and encouragement which he has imparted to it.

The vote was then put to the meeting, and passed with acclamation.

The PRESIDENT: It was tradition, or procedure, and not personal ambition on my part, which compelled the necessity for you having to listen to the reading of printed matter for a full hour; but now the ordeal is over, and we can breathe more freely. It was my maiden effort in preparing a Presidential Address; and I confess that I should have been much more happy in drawing-up a fighting paper. In this respect, I was reminded on Saturday last by the "Gas World" that it is 27 years since I gave a paper before this Institution; so I think I may justly claim to be exonerated from having been a bore to you in times past. I am afraid I was much more audacious in those days than now, because I well remember that the powers which then wielded the axe struck out all the really pithy items which might have made the paper a success. My address was not exactly what I had hoped to present to you; but if it has served any useful purpose—no matter how humble—I shall have been well repaid for my labour. I thank you very sincerely for the patient hearing you gave to me.

Annual Report and Accounts.

[See "JOURNAL" for June 1, p. 574.]

The PRESIDENT: It is now my duty to propose the adoption of the Report of the Council for the year 1926-27, and the accounts for the year ended Dec. 31, 1926. I am not aware that there is anything special that it is really necessary for me to refer to; but if there are any observations which any of you would like to make, or if there are any questions, I will do my best to deal with them. I formally move the adoption of the report and accounts.

Mr. J. FERGUSON BELL (Derby): I have pleasure in seconding the adoption of the report and accounts. The annual report indicates that the Institution has made continued progress during the past year; and I do not think there is anything to which I need draw attention, except to say how pleased we are, as a Council, that the Institution continues to progress.

The report and accounts were adopted without discussion.

Report of the Advisory Committee on Education.

Mr. F. W. GOODENOUGH then introduced the report of the Advisory Committee on Education. He said: It is now my duty and pleasure to present to you the Annual Report of the Advisory Committee on Education, and also the Special Report, together with the revised regulations of the Education Scheme which are submitted to you today for your confirmation. I will, if I may, take as read the Annual Report of the Committee; and the briefest way in which I can deal with the revision of the regulations is to read to you, with some omissions, the Special Report of the Committee dealing with them. The report has been submitted to the Council. [For the reports and Mr. Goodenough's statement see later pages.]

French Delegates.

The PRESIDENT: Before I ask Prof. Cobb to speak on the Seventeenth Report of the Gas Investigation Committee, I am sure you will join with me in welcoming a party of our colleagues from across the Channel, who have been good enough to visit us from Paris.

A hearty welcome was then given to a deputation from the Paris Gas Company, consisting of Messieurs Rançon, Simor Saint-Just, Reclus, and Joyeux.

Telegrams of Good Wishes.

The PRESIDENT: Our French colleagues have also been good enough to send us a telegram expressing good wishes in respect of this meeting; and similar telegrams have been received from the Associations in Switzerland, Belgium, and last but not least from the President of the Institution of New Zealand, who is a member of this Institution—Mr. Belton, late of Macclesfield.

Seventeenth Report of the Gas Investigation Committee.

The morning session concluded with consideration of the Seventeenth Report of the Gas Investigation Committee, on the examination of products of combustion from gas fires, which was introduced by Prof. Cobb.

List of New Officers.

The PRESIDENT: I am sure you will all be interested to hear the result of the Scrutineers' examination of the voting papers; and I formally report the elections as follows:

President: Mr. H. D. Madden, of Cardiff.

Vice-President: Mr. J. Terrace, of Lower Sydenham.

Auditors: Mr. A. E. Broadberry and Messrs. Wood, Drew, & Co.

Hon. Secretary: Mr. W. E. Price.

Members of Council: Messrs. Thomas Carmichael (Portsmouth), Ralph E. Gibson (Liverpool), Robert Robertson (Bristol), and William J. Smith (Bolton).

[Mr. John W. McLusky is the Vice-President remaining in office.]

Modern Carbonizing Economics.

On Tuesday afternoon, Mr. Thomas Carmichael, of Portsmouth, read a paper on "Modern Carbonizing Economics as exemplified by Results and Working Costs at the Works of the Portsmouth Gas Company."

Eighteenth Report of the Gas Investigation Committee.

Prof. Cobb presented the Eighteenth Report of the Gas Investigation Committee—Studies in Carbonization; Size of Coal, Admixture, Inorganic Compounds.

Benevolent Fund Meeting.

[For Report of the Committee of Management see "JOURNAL" for June 1, p. 577.]

Prior to the resumption of the business of the Institution on Wednesday morning, there was held the Annual General Meeting of donors and subscribers to the Benevolent Fund.

The PRESIDENT: I am sorry to see there are so few present; but as it is past the time for beginning our business, I will call upon the Secretary to read the minutes of the last meeting.

The HON. SECRETARY (Mr. Walter T. Dunn) read the minutes; and they were confirmed.

The PRESIDENT: I have just this moment opened a letter which bears upon the matter now in hand; but I shall be deeply grateful if you will give me permission not to read it until the beginning of the full meeting of

the Institution. I am sure you will appreciate what I have in my mind, when you hear the letter read. Now we come to the question of the report of the Management Committee and the accounts for the past year, which have been circulated; and I take it that it is my duty to formally propose that they be adopted. They speak for themselves; and I will not detain you long over them. But I would like to refer you to the paragraph of the report which states that "had it not been for the receipts from donations, which cannot be regarded as a regular source of income, there would have been a deficit at the close of the year of £35 5s. 8d." Well, as you know, it is always a source of anxiety to any organization when the expenditure exceeds the income; and your Council therefore considered it necessary to approach the District Associations, who have responded in an enthusiastic manner. I am sure that the sincere thanks of the subscribers to the Benevolent Fund, and indeed of every member of the Institution, are due to the District Associations for the way in which they have come to the assistance of the fund. I have also to report that since the last meeting our dear old friend Mr. Shoubridge has crossed the bar. He did wonderful work for the fund, and gave of his very best right up to the last. The Committee have been successful in inducing Mr. A. E. Broadberry to take the place of Mr. Shoubridge. We all know Mr. Broadberry, and we are quite sure that he will do his best in the interests of the fund. One difficulty which the Committee experience is that not more than 50 p.ct. of the members of the Institution are subscribers to the fund. I cannot preach to any of those members who do not subscribe, because I myself was for many years just as careless as they are. I am confident that, as in my case, the trouble with others who do not yet subscribe is not lack of sympathy, but sheer carelessness. The point is, of course, to get them to start subscribing; and all I can do is to ask every subscriber to the fund to be good enough to use his influence to induce non-subscribing friends to start doing so right away. I have never served on the Committee prior to taking up my present position; but I must say I am deeply impressed with the practical way in which the Committee carry out their duties. It is very distressing to find there are so many cases in which assistance is required. I know that everyone present is an enthusiast in promoting the welfare of the fund; and therefore I will not detain you longer, but will formally move the adoption of the report and accounts.

Mr. J. T. LEWIS (Wellingborough): I will second that.

The PRESIDENT: Does anyone wish to make any observations?

Mr. L. J. LANGFORD (Tunbridge Wells): As a member of the Committee, I should like to express the hope that every member of the Institution will rally to the support of the President in his appeal. It would be very nice to have 100 p.ct. of the members subscribing something to this fund.

The PRESIDENT: If there are no other remarks, I will ask you to approve of the report and accounts. That is carried; and it completes the business relating to the Benevolent Fund, unless anyone present desires to bring any special matter forward.

The business of the Institution was then resumed.

A Handsome Donation.

The PRESIDENT: The subscribers to the Benevolent Fund gave me permission to delay the reading of a letter which has just come to hand. It is as follows:

June 14, 1927.

DEAR MR. PRESIDENT,—Although no longer actively associated with the management of the Benevolent Fund, I can testify to the good work which has been, and is being, done. In appreciation of this, and in recollection of many kindnesses from my colleagues, I ask your acceptance of the enclosed cheque (for investment); and I would like the donation, so far as may be convenient, to be identified with the names of Charles Edward Botley and Ellen Jane Botley.

Please excuse my absence this morning, as I am required at 28, Grosvenor Gardens (Gas Charges Committee). The cry will still be for more annual subscriptions, however small. How long will that continue to fall on deaf ears?

Yours sincerely,
CHARLES F. BOTLEY.

The PRESIDENT: I have much pleasure in saying that the cheque is for £100. It is now my pleasant duty to propose that the best thanks of the Institution be forwarded to Mr. Botley for his extreme kindness and generosity in giving a lead with regard to donations to the Benevolent Fund.

Mr. OCTAVIUS THOMAS (Pentre): I have much pleasure in seconding that.

The vote of thanks was given with acclamation.

Election of New Members.

The PRESIDENT: I informed the meeting yesterday afternoon that the Scrutineers had reported the approval of all the applications for membership and the transfers. I see before me a statement to the effect that the President will introduce the new members; but I am quite sure the new members would not thank me for asking them to come up to the platform. I will therefore cut these proceedings short by extending to our new members a very hearty welcome to our circle. I sincerely trust they will always enjoy the proceedings at our meetings.

MEMBERS.

Adlington, Lawrence Spencer, Engineer, Gas-Works, Worcester.

Bain, Lewis, Engineer and Manager, Cullen District Gas Company, and Banff and Macduff District Gas Company.

Batt, William, Distributing Superintendent, Newcastle-on-Tyne and Gateshead Gas Company.

Bolton, Wilfred, Engineer, Manager, and Secretary, Raunds Gas Company, Northants.

Clark, Alan McGlashan, Engineer and Manager, Gas Department, Port Glasgow.

Davies, Daniel Walter, Gas and Water-Works Manager to the Tredegar Urban District Council.

Gray, Robert, Assistant Engineer and Manager, Gas-Works, Greenock.

Holliday, James Earl, Manager and Secretary, Gas-Works, Otley.

Kyle, Archibald Thomas, Engineer and Manager, Corporation Gas Department, Abergavenny.

Laurie, George Peters, Engineer and Manager, Corporation Gas Department, Dunoon.

Macfarlane, Gilbert Reid, Engineer and Manager, Corporation Gas Department, Tipton.

Macleod, James, Manager, Corporation Chemical Works Department, Glasgow.

Mitchell, Herbert Victor, Engineer and General Manager, Gas-Works, Brighton, Victoria, Australia.

Oughton, Ernest Leonard, Gas Sales Superintendent, South Suburban Gas Company, London.

Pattison, John, Manager and Secretary, Gas-Works, South Elmsall, Yorks.

Philp, Robert James, Engineer and Manager, Gas-Works, North Berwick.

Reynolds, Thomas, Assistant Engineer and Manager, Corporation Gas Department, Blackpool.

Royden, Thomas, Engineer, Gas-Works, Uddingston.

Sim, Peter Moncrieff, Engineer and Manager, Gas-Works, Buckie.

Simpson, Robert Macdonald, Engineer and Manager, Denny and Dunipace Gas Department.

Stocker, Frank Ernest, Manager, Gas-Works, Highbridge, Somerset.

Swan, James Waldron, Resident Manager, Hitchin and District Gas Company.

Thomas, Alfred, Engineer, Manager, and Secretary, Gas-Works, Wellington, Somerset.

Thomas, Harold Hirst (Institution's 1st Class Diplomé in Gas Engineering, 1926), Senior Assistant Chemist, Liverpool Gas Company.

Thompson, John William, Gas and Water Engineer, Barnoldswick, Yorks.

Wainwright, John Herbert, Engineer and Manager, Gas-Works, Halesowen.

Wilkinson, Arthur, Manager and Secretary, Gas-Works, Beighton, Yorks.

Young, Donald, Chief Chemist, Corporation Gas Department, Nottingham.

ASSOCIATE MEMBERS.

Adams, Henry Standfield, Assistant Engineer and Manager, Gas-Works, Bilston.

Cornish, James Hughes, Junr., Works Manager, Gas-Works, Bridgwater.

Dobson, Wilfred Allison, Assistant Engineer and Manager, Gas-Works, Ilkley.

Edwards, Edward Morgan, Technical Assistant, Corporation Gas-Works, Holyhead.

Gibbins, Reginald Eric, Shift Chemist, Tottenham District Light, Heat, and Power Company.

Gould, John Alexander, Assistant Mains Superintendent, South Metropolitan Gas Company.
Hammond, Stanley Waynforth, Works Chemist, Gas-Works, Eastbourne.
Hill, Robert McGregor, Chemist, Newcastle-on-Tyne and Gateshead Gas Company.
Keillor, George Edward Hamilton, Assistant Engineer and Manager, Corporation Gas-Works, Dunfermline.
Lawrence, Henry Michael, An Assistant Engineer, Beckton Station of the Gas Light and Coke Company.
Nash, Edwin Charles, Technical Assistant, Rotherhithe Station of the South Metropolitan Gas Company.
Newham, Cecil Augustus, Assistant Works Manager, Meadow Lane Works of the Leeds Corporation Gas Department.
Pyper, Frederick Gerrard, An Assistant Engineer, Fulham Station of the Gas Light and Coke Company.
Robin, Allan, Assistant to Engineer and Manager, Gas-Works, Holywood, Co. Down.
Sansom, Fred William, An Assistant Engineer and General Manager, Gas-Works, Exeter.
Saunders, Rupert Henry, Assistant Manager, Gas-Works, Slough.
Shaw, William Henry, Junr., Junior Assistant, Basford Works of the Nottingham Corporation Gas Department.
Simpson, Albert Edward, Works Assistant, Corporation Gas Department, Nottingham.
Stephenson, William Edward, Chemist, South Bank and Normanby Gas Company.
Walker, Maurice, Chemist and Junior Assistant, Gas-Works, Lea Bridge, Essex.
Wood, Charles Comely, Assistant Manager, Gas-Works, Wellingborough.

ASSOCIATE.

May, Cyril Archibald, Technical Assistant to the Gas Referees, 66, Victoria Street, London, S.W. 1.

Ovens as a Gas-Works Carbonizing Plant.

The first paper taken on Wednesday was that by Mr. G. M. Gill, of London, entitled "Ovens as a Gas-Works Carbonizing Plant."

Gas Research Fellowship Report.

This was followed by the report of the Institution Gas Fellowship on "Influence of the Ash Constituents in the Carbonization and Gasification of Coal." The report was submitted by Prof. Cobb.

Greetings from America.

The PRESIDENT, at the opening of the afternoon session, said: A telegram has just been received from the American Gas Association, sending heartiest greetings and best of good wishes for a pleasant and successful meeting.

Edinburgh Coal Cleaning Conference.

The PRESIDENT: I am requested by Dr. E. W. Smith to remind members of the Institution that an invitation has been extended to them by the Joint Committees to the Edinburgh Coal Cleaning Conference on July 7, and that our members are invited to join in all the functions of the week's meetings of the Society of Chemical Industry.

Coke Cooling.

Mr. JOHN P. LEATHER, of Letchworth, read a paper on "Coke Cooling."

Refractory Materials Report.

The proceedings concluded on Wednesday with the presentation by Mr. Leather (the Chairman) of the report of the Refractory Materials Joint Committee.

Treasurers' Greetings.

The PRESIDENT, at the commencement of Thursday's session, said: We have just received a telegram from the Institution of Municipal Treasurers, assembled in annual meeting at Eastbourne: "Send cordial greetings and best wishes for successful conference."

Gas Service.

Mr. J. HERBERT CANNING, of Newport (Mon.), then read the final paper of the meeting, which was entitled "Some Experiences of Gas Service."

The New President.

The PRESIDENT: At an earlier sitting I unofficially informed you of the result of the ballot. It is now my duty to do so formally. The new President is Mr. H. D. Madden, of Cardiff; while the new Vice-President is Mr. John Terrace, of Lower Sydenham. [Applause.]

Mr. H. D. MADDEN (Cardiff): It is very difficult for me to get up and tell you how much I feel the honour that you have conferred upon me by making me your President for the coming year. Believe me, I will do my very best to uphold the traditions of that high office. I realize that those who have occupied the chair before me have been very big men in the industry, and it will need my utmost efforts to live up to the standard they have set; but, as I have said, I will do my best. In thanking you for this great honour, I should like to say that, not only do I take it to myself, but my Company also regard it as a great honour, the city of my adoption regards it as a great honour, and the Principality of Wales will regard it as a great honour. This is the first occasion in the history of the Institution on which you have given that honour across the Severn into Wales. I am not a Welshman; but I have lived there for 21 years, and I know that the City of Cardiff has heard about this matter, and is very proud of it. I should like to extend an invitation to you to hold next year's meeting in the Metropolis of Wales—Cardiff. [Applause.] It is really two cities rolled into one—Llandaff and Cardiff, the ancient and the modern. It is the biggest export port in the world; and it has the finest country and seaboard and the most handsome civic buildings of any city of this Empire. I am proud of Cardiff; and I hope that next year you will come there. I can assure you that you will have a very warm welcome. My Directors said to me the other day: "It is a great honour to you, Madden, and to the Company. Will you let us share it with you?" When I tell you that I do not think there is an engineer in this country who has such good Directors—such kindly ones—you will appreciate what they meant when they said that. In conclusion, I suppose I ought to thank you in Welsh, so I will say: "Diolch-an-Fawr."

The Vice-President.

Mr. JOHN TERRACE (Lower Sydenham): I want to assure you that it is through no desire on my part that I am standing in the honourable position which I occupy to-day. Proud I am of it, and it is perhaps wrong to say I did not desire it; but I did not do anything to try to gain it. I was quite content to continue working in the background on the various Committees and similar positions in which I could be of use to the Institution; but the Council did me the very great honour of asking if I would be prepared to take up the position of Vice-President, if they put my name on the balloting list. I thank them for having done so and I thank the members for having recorded their vote in my favour. The work which I shall now be called upon to do will, I have no doubt, differ from that which I have been called upon to do for some years past for the Institution; but I can assure you that it will not be because of want of effort, want of application, or want of time on my part if I am not able to uphold the position to which you have been so good as to elect me.

Presidential Certificate.

Mr. MADDEN: I have one duty to perform before the meeting is over. It is a pleasing duty in one way, but a sorrowful one in another. It is to present to the President on your behalf the Institution's certificate. In doing so, I know I shall be expressing the views of all of you when I say that Mr. Wilkinson has fully maintained the high traditions of the office. He has added prestige to that position; and right throughout there has been that kindly feeling, that kindly personal note, which he has struck at all times. [Applause.] I have learned to know him and to love him in the Council Room, where we have met during the past year on many occasions; and I am sure I am expressing the views of the Council in saying that he has been a very popular and a very good President. I should like, in presenting him with this certificate, to add that we hope in coming years he will look back with the greatest pleasure on his year of office, and that renewed health may enable him to overcome the disability from which he has suffered during that period. [Applause.]

The PRESIDENT: I can assure you in all sincerity that in years to come a glance at this certificate will bring back

to me a time of service in the interests of the Institution when I met with nothing but kindness and assistance from my colleagues. I have undoubtedly suffered during my period of office from certain ill-health; but from the moment when I took control until this morning, when I am about to lay down the reins of office, I have received nothing but kindness and help from every member of the Council, from every official, and from you, gentlemen. My period of office as President has had the happy result of binding more strongly old friendships and enabling me to form new friendships, which I sincerely trust may continue as long as I live. I can only say that in years to come this certificate will bring back to my mind happy recollections of the times I have spent with my friends in the industry.

Votes of Thanks.

Mr. J. H. BREARLEY (Southport): The resolution which I am rising to propose is a very important one. It is that our best thanks for their services be accorded to the Council, the Hon. Secretary, the authors of papers, the Research Committees, the Scrutineers, and the Auditors. Though time is getting on, I must say two or three words in connection with this resolution. We have heard from the President how loyally the Council and officers have supported him during his year of office. That is sufficient to justify the resolution so far as the Council are concerned. But before proceeding further, I must digress for a moment to say how proud I have been this year to be here to support Mr. Wilkinson, who is a very old friend of mine, and how proud I have been to note the high standard he has set in every respect in connection with the work of the Institution. As to the Hon. Secretary, we are all delighted to have Mr. Price with us. He is indefatigable; and he is second to no one in service to the Institution. Now the authors of papers. I am very glad to see that in our proceedings we have had a good choice of papers and authors. I do not think it would have been possible to find more appropriate men to bring forward the subjects that have been dealt with in these sessions. The Research Committees work behind the scenes; but I know you are eminently satisfied with these researches. The Scrutineers and the Auditors are not in the limelight; but they also do good work for us.

Mr. RALPH HALKETT (Sheffield): It gives me great pleasure to second this vote of thanks. We are all much indebted to the gentlemen to whom Mr. Brearley has referred. The past year has been a very trying one to us all, and our duties have been heavy; but yet these gentlemen have been able to do work the success of which has been proved at these meetings. With reference to Mr. Price, I would like to emphasize our appreciation of his services, and to say that the longer we have these services the better we like him

The resolution was carried with acclamation.

Mr. C. F. BOTLEY (Hastings): It is my privilege to thank you on behalf of the Council. Of course, you elect your Council; and it has been said that people have the government which they deserve. If you are satisfied with the efforts of your Council, I am sure that we are delighted to serve in the interests of the industry. We are only too glad to feel that what we do meets with your approbation.

Mr. W. E. PRICE (West Chobham): I am not given to long speeches. I would rather sit and listen, and perhaps pull people's coat-tails if they take up too much of the time of the meeting. [Laughter.] But I seem to be becoming an institution here—an institution within an Institution. I have seen thirteen of your worthy Presidents through the chair. I have honoured the king, and I have said: "The king is dead, long live the king." I shall be saying it again presently. If I have given you satisfaction, I can only say that it has been a pleasure to me to do what I have done. The position that I hold here has made for me very many friends; and I can say with equal emphasis and truth that not one enemy have I ever made in this Institution.

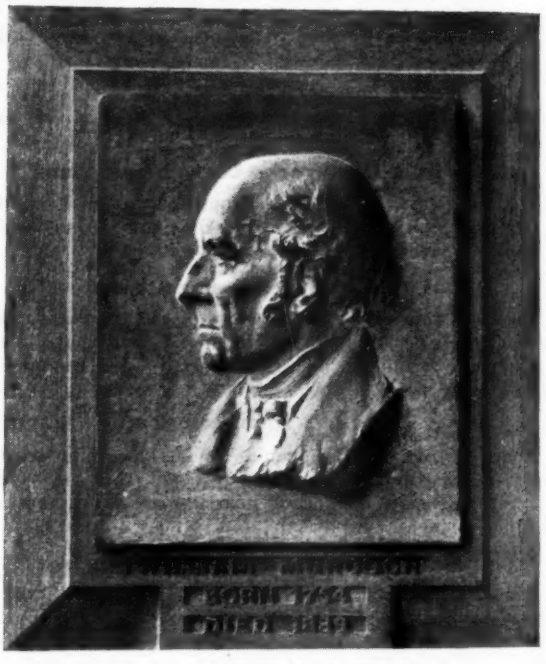
Mr. T. CARMICHAEL (Portsmouth): It is my duty to acknowledge on behalf of the authors of papers your kind vote of thanks. I think I can honestly say for all the authors that a considerable amount of time was spent in preparing the papers, but that nevertheless it was a work of pleasure. They realize that it is an honour to be asked to contribute to the proceedings of the Institution.

Mr. S. GLOVER (St. Helens): I have to thank you on behalf of the Research Committees. We want you to continue to take a great interest in their work. We thank you for your support of the endeavours of the Committees to carry out their work; and we want you to communicate to them any matters you would like to have included in their investigations.

The PRESIDENT: I am sure the members would like to hear a few words from the "chief carbonizer," who is responsible for so much of the success of this meeting. I refer to our friend Mr. Dunn, the Secretary.

Mr. WALTER T. DUNN: It is extremely kind of the President to call upon me. Sometimes, perhaps, I feel that I am a bit of a nuisance to some of the members of the Council; but it is all done with the intention of helping the Institution forward. I have to thank the Council and the members generally for the kindness they show to me, and I should like to say how loyally my staff assist me in my work.

Mr. TERRACE: Whatever may be the views of the members of the Institution as to the desirability or the possibility of having a building of our own—a home in London—I am sure we should not like to disperse to-day without showing our gratitude to the Institution of Electrical Engineers for giving us the use of this beautiful place for our meetings. We can only do this by a vote of thanks, because the Institution refuse to make any charge for the use of their building. As to its suitability for our meetings, there can be no two opinions; and I think a large amount of good feeling by the Institution of Electrical Engineers towards the Institution of Gas Engineers is shown by the fact that this is not the first occasion on which we have held our meetings here. I move that a vote of thanks be given to the Institution of Electrical Engineers for their courtesy in having granted the use of this building for our annual meeting.



The Bronze Medallion presented by Mr. J. W. Napier, of Alloa.

In the annual report of the Council of the Institution, the following reference was made to this presentation: "Thanks are specially due to Mr. J. W. Napier, of Alloa, for his gift of a beautifully executed bronze oak-mounted mural medallion of William Murdoch, by Mr. H. S. Gamley, A.R.S.A., Edinburgh. It is a reproduction from the original plaster model of the bronze medallion which was placed on the house at Bello-Mill, Lugar, Ayrshire, the birthplace of Murdoch, by the North British Association of Gas Managers in 1913, and unveiled by the late Mr. G. R. Hislop, of Paisley."

Mr. H. E. COPP (Hull): It is a privilege to be allowed to second that. I think unquestionably we may interpret this kindness on the part of the Institution of Electrical

Engineers as a very friendly "gesture." ["Hear, hear."]

Place of Next Meeting.

The PRESIDENT: Now we have to consider the place of meeting next year. I take it that, as a matter of fact, this has really already been decided, by the manner in which you received the suggestion put forward by Mr. Madden that our meeting next year should be in Cardiff; but I understand it is necessary for me to take a formal vote on the subject. Therefore I propose that our next meeting be in Cardiff.

Mr. S. GLOVER seconded this, and it was unanimously agreed to.

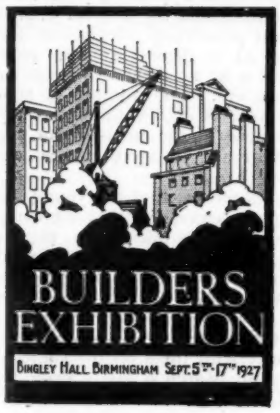
Acknowledgment of the President's Services.

Mr. J. E. BLUNDELL (Carlisle): It is a most pleasant duty that I have been asked to undertake—namely, to propose a vote of thanks to our President. I do not wonder that the previous speakers, one after another, have transgressed, and been anxious to give expression to a vote of thanks themselves for the work our President has done during the past year. We are very jealous of our Presidential Chair; and year after year we have it occupied by men of distinction. I venture to say that this year Mr. Wilkinson has maintained the highest traditions of the office and upheld the dignity of it. The remarkable attendances at the sittings this week have been a fine tribute to the President. Our admiration of Mr. Wilkinson has grown day by day. We have learned to love him; and we are hoping that his health will soon be restored. I would like to mention the magnificent reception we had on Tuesday night. ["Hear, hear."] For that our thanks are due to the President and Mrs. Wilkinson. In conclusion, I want to say in all sincerity that we are grateful to our President. We do appreciate all that he has done during his year of office.

Mr. JOHN WILSON (Motherwell): I rise with a little diffidence, and yet with a great amount of pleasure, to second this vote of thanks. The position of President of this Institution is becoming more and more arduous, onerous, and difficult to fill. It requires a man with a big heart; and in our President, I think, we have such a man. ["Hear, hear."] I thought of the word "President;" and I said to myself that in the letters comprising it I had my points for seconding the vote of thanks. He has "prestige;" he is "resourceful;" he is "energetic;" he is "safe;" he has made an "ideal" President, because he has put "duty" first, and has carried it out with "efficiency." He comes from "Nottingham;" and as a President he has turned up "trumps."

Mr. W. H. POWIS, J.P. (Tipton): I should like to take the opportunity of supporting this vote of thanks, for the simple reason that I am not a gas engineer, but just an ordinary member of a Committee, who have been good enough to ask me to attend, with our Manager, this conference. It is the third which I have been privileged to attend; and therefore I can speak with some knowledge of Past-Presidents and of the efficiency of your present President. If more members of committees of local authorities could have the opportunities that I have had of being present at your meetings, I feel certain they would not have the opinion which some of them have got that it is a waste of time to attend. Managers of municipal gas undertakings who are here may have experienced something of what I mention; but I am convinced that these conferences are of great educational value to those attending them. [Applause.]

The PRESIDENT: I thank you very much indeed for your kindness. As I have already occupied a considerable amount of time speaking, I do not intend to say much now; but I must let you know how much I appreciate all that you have said. If my services during my year of office have been of any assistance, I am amply repaid. As regards thanks, what thanks are necessary? What could a man enjoy better than three days in the company of British gas engineers?



President: The Right Hon. The Lord Mayor of B'ham (Ald. A. H. James, C.B.E.)

MIDLAND BUILDING
AND ALLIED
TRADES EXHIBITION
(including Public Works and Road Making Section)

BINGLEY HALL, BIRMINGHAM, SEPT. 5 to 17, 1927.

IN RESPONSE TO the general request of Exhibitors at the first Exhibition two years ago, the Birmingham Chamber of Commerce (Inc.) has arranged to hold a similar display, on a still larger scale, in the coming Autumn.

ALL ASPECTS OF Modern Building will be represented. The following is the Schedule of Exhibits:—

Building Materials.
Builders' Ironmongery & Hardware.
Architectural and Ornamental Work.
Constructional Steelwork.
Ferro-Concrete.
Sanitary Apparatus, Appliances and Fittings.
Contractors' Plant.
Shop, Bar and Restaurant Fittings.
Municipal Engineering Equipment.
Road Making Plant and Materials.
Paints, Varnishes, Colours, Enamels, Stains, Polishes, Lacquers, Metal Powders, Wood Preservatives, Glues and Adhesives.
Mechanical and Hand Painting and Spraying Apparatus.
Decorating Materials, Wall Papers and Coverings.
Electrical, Gas, Oil and other Illuminating and Heating Plant and Fittings.

UNDER THE AUSPICES of the leading Architectural and Trades Associations, Conferences on Technical subjects and problems of the day will be held throughout the Exhibition in a Conference Pavilion specially erected for the purpose. Arrangements have also been made for the entertainment at Luncheon, day by day, of influential trade delegations.

The greater part of available space having been booked in advance by Exhibitors in 1925

EARLY APPLICATION IS ESSENTIAL

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The
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The Chamber of Commerce (Inc.),
Birmingham.

ANNUAL REPORT OF THE ADVISORY COMMITTEE ON EDUCATION.

The past year has witnessed a steady development in the work entrusted to the Committee. Though the progress has not been as great as it could and should be, it is not unsatisfactory to be able to report that the number of candidates who entered for the examinations this year was 211, of whom 110 were internal and 101 external students. The total entries in 1925 were 108, and in 1926 they were 162. There has been therefore a 30 p.ct. increase this year, following a 50 p.ct. increase in 1926.

Of the entries, the numbers in Gas Supply have again been disappointing. There have been no entries for the Diploma, only 18 for the Higher Grade, and 59 for the Ordinary Grade. It will be agreed that these numbers fall far short of the requirements of the industry. There is, however, reason to expect a considerable increase in the near future.

It is rather disappointing to find that out of 30 technical institutes in the country having approved schemes, only 14 have presented candidates for examination this year. Two additional technical institutes have had their schemes of instruction in Gas Engineering and Gas Supply approved by the Committee during the year—namely, the Wigan and District Mining and Technical College, and Southampton University College.

At the request of the Examiners in Gas Engineering an addition has been made to their number in the person of Mr. H. C. Smith, Assoc.M.Inst.C.E., of Tottenham.

At the same time, in order to co-ordinate more closely the Minor Grouped Courses in Gas-Works Practice and Gas Supply Practice with the Major Grouped Courses in Gas Engineering and Gas Supply, the Examiners for the City and Guilds of London Institute in the Minor Grouped Courses (Mr. John Terrace, M.Inst.C.E., and Mr. J. P. Leather, M.Inst.C.E.) have been invited to join, and have become members of, the Institution's Board of Examiners.

The attendance at the Annual Conference of the Advisory Committee, the Examining Board, and the Consultative Committee, with the teachers of Gas Engineering and Gas Supply in July last, was exceedingly good, and much benefit must undoubtedly accrue to the industry from these frank interchanges of opinion on the working of the Education Scheme.

A valuable development this year has been the inception of a Teachers' Training Course. This has been arranged at the suggestion and through the good offices of the Board of Education, for the benefit of the teachers in Gas Engineering and Gas Supply. The Board is paying travelling expenses for all recognized teachers attending. The Course will be held during the week July 16 to 22, inclusive. It is hoped that guidance thus given to non-professional part-time teachers in the art of teaching will result in the improved training of students throughout the country.

Those who represent the gas industry on this Committee desire again to record the great assistance rendered in the working of the Education Scheme by the representatives of the Board and Departments of Education. Their expert knowledge has been placed unreservedly at the services of the Committee, and has been invaluable in the working-out of the many details and surmounting the many difficulties incidental in its early stages to a national technical education scheme such as that of the Institution.

Considerable discussion has taken place during the past few months on the provisions of the Scheme in so far as they relate to the education and examination of isolated students. A conference was therefore held, on March 9, of the Advisory Committee, the Board of Examiners, and the Committees of Advice for Scotland and Wales, with representatives of the Junior Gas Associations of the United Kingdom; and further discussions have since taken place. As a result, a special report proposing sundry modifications of the regulations has been presented to the Council for submission, if approved, to the Annual Meeting of the Institution. These proposals also embody a careful revision of the syllabuses in the light of experience, especially of those relating to Gasfitting. The Gasfitting Course has been found to be too elaborate and scientific, and has been revised to provide a course suited to the needs of the gasfitter as a craftsman. (For fitters who desire education to fit them for other grades of employment on the gas supply side of the industry, the Minor Course in Gas Supply Practice is available, if the Major Course in Gas Supply is beyond their capacity or opportunities.) If these proposals are adopted, the Committee believe that the Scheme will be such as will meet the education needs of the industry as completely as possible.

F. W. GOODENOUGH, *Chairman.*

May 24, 1927.

APPENDIX.

List of Schools and Colleges Giving "Course" Instruction Under the Scheme of the Institution of Gas Engineers.

Bath Municipal Technical College, Barnsley Technical School, Birmingham Municipal Technical School (*Coventry Technical Institute* and *Wolverhampton Technical College* for early years of Course only), Blackburn Municipal Technical College, Bournemouth Municipal College, Bradford Technical College, Bristol—Merchant Venturers Technical College, Burnley Municipal College, Cardiff Technical College, Coventry (see Birmingham), Derby Municipal Technical College, Dewsbury Technical College, East Ham Technical College, Edinburgh—Heriot-Watt College, Glasgow—Royal Technical College, Halifax Municipal Technical College, Huddersfield Technical College, Leeds Central Technical School, and Liverpool Central Technical School.

SPECIAL REPORT ON PROPOSED REVISION OF REGULATIONS OF EDUCATION SCHEME.

TO THE PRESIDENT AND COUNCIL OF
THE INSTITUTION OF GAS ENGINEERS.

GENTLEMEN,

While the number of students taking courses and entering for examination under the Institution's Education Scheme is steadily increasing, as is also the number of Technical Institutions at which courses have been approved, your Advisory Committee have felt for some time that the number of students entering upon instruction and presenting themselves for examination was not as great as is desirable and possible; though the paucity of students is by no means so great as has been represented in some quarters. The number of students entered for examination this year is double that of two years ago. At the same time the need of the industry for highly-trained and skilled officers is greater to-day than ever, and is constantly increasing.

It recently became evident, moreover, that the young men in the industry, especially in certain areas, felt that the comparatively small number of students was due partly to circumstances over which they had little or no control, and partly to requirements laid down under the Scheme which a considerable number of would-be students found it difficult or impossible to fulfil.

Your Committee therefore invited the Junior Associations to send representatives to confer with them on the subject, and such a conference took place on March 9 last. Prior to and since that conference your Committee have given the subject much consideration, and now submit the following observations and recommendations:

1. The Committee find that, in so far as the number of students is less than is desirable and possible, the main causes are:

(*a*) Apathy, indifference, and failure to afford reasonable facilities and justifiable financial assistance to would-be students in their service on the part of many gas undertakings.
(*b*) Want of knowledge by potential students of the provisions of the Scheme and of the lines on which it is administered by your Committee.
(*c*) Difficulties inherent in the scattered nature of the industry.
(*d*) Provisions of the Scheme which at present debar a number of students from entering upon it, but might be modified without materially affecting the value of the Scheme as an instrument for the advancement of education in the industry.

2. In considering any means for removing or reducing those causes, we have had foremost in mind the purpose for which the Scheme was initiated and designed by the Institution and has been administered throughout by its Committee—namely, to secure the satisfactory education, and not merely the ex-

amination and certification, of those engaged in gas engineering and gas supply.

3. Those who instituted this Scheme and those who have the administration of it have alike held that no certificates or diplomas can be of real value as evidence of the fitness of their possessors for appointment or promotion to positions in the industry, unless they are based upon something more than the capacity of candidates to answer examination questions—namely, upon the satisfaction of the certifying authority that the student has pursued and profited by an adequate course of study under qualified direction and tuition in a properly equipped educational institution or works laboratory.

4. Within the limits of that fundamental principle your Committee have been and are prepared to give such interpretations to, or recommend such modifications of, the provisions of the Scheme as will meet the special cases of individual students or the general needs of categories of students; and many students have been dealt with specially under the discretions entrusted to us under the Scheme.

Those discretions the Committee have, in fact, exercised generously in these early days of the Scheme; always having reasonable regard to the necessity for maintaining a high standard by which to judge the qualifications of students.

But the Committee are not prepared to recommend the Council to depart from the fundamental principle laid down in paragraph 3 above, upon which their Scheme was originally based. In particular they are not prepared to recommend the acceptance of tuition by correspondence as satisfying the requirements of the Institution's Scheme of Education.

5. We are of opinion that, without departure from the fundamental principle of a course of study under approved direction in approved premises, the needs of practically all would-be students in the industry can be met—given reasonable co-operation and assistance by their employers—if the Scheme be amended in accordance with the following proposals, which we recommend should be adopted at the earliest possible date. The verbal amendments necessary to carry those proposals into effect are embodied in the revised and rearranged Regulations appended hereto, but their general effect is as follows:

PROPOSED AMENDMENTS.

6. With a view (*a*) to arousing interest among, and enlisting the support of, gas undertakings throughout the country; (*b*) to assisting to make the Scheme known to and appreciated by potential students; (*c*) to advising would-be students as to the courses and facilities available and best suited for their individual educational requirements; and (*d*) to assisting generally in the administration of the Scheme; it is proposed that District Education Committees should be set up throughout the country, to comprise not more than 9 members—

Not more than 4				nominated by the District Institution or Association of Gas Engineers.
" "	" 4	"	"	Junior do.
" "	" 1	"	"	Board or Department of Education,

with the Organizing Secretary as an additional *ex-officio* member.

7. Your Committee have given very careful consideration to the possibilities of increasing the facilities for students (*a*) to obtain instruction in ancillary subjects under Section II., and (*b*) to attend courses under Section 1. without undue fatigue and loss of time due to travelling. While of opinion that the most effective means of giving part-time instruction is that afforded by the Technical Colleges already approved for this purpose, we are aware that many students are prevented from taking full advantage of this provision, partly because the classes are held in the evening only, and partly because the students live at long distances from the schools.

If, however, a number of the gas undertakings in the areas surrounding these Technical Colleges would co-operate in arranging for the release from employment of would-be students on at least one half-day a week in order that they might attend school, there is no reason to doubt that the Education Authorities concerned would be willing to make the arrangements necessary for their proper instruction. [I think I am right in saying that this arrangement has already been made in South Wales.]

There are, however, parts of the country lying outside the areas of influence of the greater Technical Schools. In many of these parts there are smaller Technical Schools which can, without difficulty, provide instruction in subjects ancillary to Gas Engineering or Gas Supply, and these should be used wherever possible. It would obviously be the business of the various District Committees to make themselves fully acquainted with the actual or possible facilities of these schools, and to advise any prospective students as to the classes which they should join.

In the comparatively rare instances where no suitable Technical School is within reach of the prospective student, the District Committee would be authorized to make arrangements, if possible, either directly or through representatives of the local gas undertakings, with the authorities of suitable Secondary Schools for the instruction in ancillary subjects of students released from employment during the daytime. Cases exist where this arrangement has been made already by your Committee with the consent of the Governing Body of the Secondary School and the goodwill of its headmaster, and it is hoped that their number will be increased. In special cases, moreover, the District Committee would be authorized to arrange for the special tuition of students in ancillary subjects where the general instruction, at either the Technical or Secondary Schools, does not reach our prescribed standard; and to provide for their examination in those subjects either at the school at which they have received instruction under this arrangement or at the nearest approved Technical School.

Under this plan it will be permissible for a student to study his ancillary subjects at a Secondary School in his home town or one within easy access, while studying Gas Engineering or Gas Supply in his third or fifth year at a Technical School less easily reached but not too far distant for him to attend it on one night per week during one session.

It should, however, be remembered that the normal plan is that students of Gas Engineering or Gas Supply should attend for instruction in Technical Schools, and that attendance at Secondary Schools must be regarded as exceptional.

It is believed that the active and systematic co-operation of the District Committees with Education Authorities would greatly increase the number of schools at which students desiring to enter under Section II. could obtain instruction in the necessary ancillary subjects.

8. To remove obstacles from the way of students who have received adequate instruction in ancillary subjects in former years, but not under a prescribed course under the Scheme, and are now desirous of entering for examination, whether for the Ordinary or for the Higher Certificate or for the Diploma, it is proposed to extend the discretionary powers of your Committee in the following ways:

(*a*) They shall have power to dispense with the possession of the Ordinary Certificate by students desirous of entering for the Higher Certificate (under either Section I. or Section II.) who can satisfy them that they have in earlier years received and profited by instruction in Gas Engineering or Gas Supply and in the requisite ancillary subjects up to the standard required for the Ordinary Certificate.

(*b*) Until June 30, 1930, they may accept for examination in Gas Engineering or Gas Supply students who have not fulfilled all the prescribed conditions but can produce satisfactory evidence of their standard of attainment in some or all of the ancillary subjects of an approved course. (The Board or Department of Education will only be able to endorse the certificates in such cases if the student has fulfilled all the prescribed conditions in the last year of the course.)

(*c*) They shall have power to excuse (during a part or the whole of a course) attendance at the approved Technical School at which a student is studying Gas Engineering or Gas Supply, in any ancillary subjects in which they are satisfied that he has received or is receiving satisfactory instruction at a Secondary School or elsewhere (as, for example, in a works school or laboratory).

(*d*) They shall have power to exempt candidates for the Diploma:

(1) from possession of the Higher Certificate, students who, being over 27 years of age and engaged on the practical side of the industry for not less than 5 years, satisfy them that they have received instruction and possess knowledge of that subject and its ancillary subjects up to the standard required for the Higher Certificate (First Class);

(2) from the proviso as to evidence of general education, students who were 25 years of age or more on Jan. 1, 1927, or who, irrespective of age, present themselves for examination before June 30, 1932.

We unanimously recommend that the revised Regulations embodying the foregoing proposals (submitted herewith) be approved and put into effect as soon as possible.

For the Committee,
F. W. GOODENOUGH,
Chairman.

28, *Grosvenor Gardens*,
May 10, 1927.

[The revised and rearranged Regulations were appended.]

Thereafter, Mr. GOODENOUGH said: These are the proposals which the Committee has submitted to the Council, which the Council has approved, and which the Committee is able to say meet, as far as is practicable and possible, the wishes of the Junior Associations. We are very glad indeed that we have been able to find ways of meeting the difficulties that have arisen and to satisfy the Juniors that no obstacles now exist for almost any would-be student to get proper education and entry under the Scheme. It was very welcome to the Committee that the Junior Associations showed such very keen interest in the subject. That was proof that the value of the Scheme was being realized by the Juniors and that they were anxious, all of them, to be able to come within it. The Scheme, we believe, will be of the very greatest value to the industry in the future;

but much depends—and that is a point the Committee is very anxious to stress—on the attitude of the seniors towards the Scheme and towards the desire of the Juniors for education, and much also depends on the attitude of the undertakings themselves; on the employers, in giving the necessary facilities to students in the way of time off. In that connection let me mention that I have received from our friend Mr. Abbott, of the Board of Education—who has done so much in helping us to develop this Scheme, and whom we are pleased to see here to-day—information as to what employers in other industries are doing in the matter of giving time off to their employees to attend part-time schools; and I may say that the study of the information he has given me makes me feel that the gas industry has to go a long way before it catches up some of the other industries of the country. In London alone, in the printing trade, 1250 students are given a whole day off every week to attend educational institutions at the expense of the employers; and if the gas industry will follow the example that is being set by other industries in the matter of facilities to their employees for obtaining education, we have every evidence that the Juniors will be very glad to avail themselves of these facilities.

The President has referred to the gas industry as treading the path of progress in the past and in the future. If we are to be the great public service that we can be, and are all aiming to be, we must remember that we can only serve through our servants. We can only serve through our staffs; and therefore on the capacity and training and development of our staffs very largely depends the future of this great industry. Therefore it is up to the industry to do everything that is possible to improve the education and training of every grade of the staffs.

I want to mention in that connection—and I will not take up the time of the meeting much longer—that the revised Regulations put before you to-day contain a revision not only of the Regulations, but also of the Syllabuses, particularly in regard to gasfitting, which has been drastically revised in the direction of simplification, and of making it truly a craftsman's course, and not a course that could only be taken up by a man who, when he had taken it, would not be content to remain a gasfitter but would be looking for promotion far beyond that. What is very badly needed in the industry to-day is a proper craftsman's course of training for gasfitters, as a foundation of the service to be rendered to the public. Above that come the minor and major courses of gas supply and gas engineering which are revised, not drastically but in the light of experience, to make the ladder by which all the employees on both sides of the industry can climb. In the Annual Report we mention the fact that for the first time, this year, a course of training for teachers is being instituted, to which we attach great importance, because if the teachers—who are drawn from the industry and their qualification is the possession of knowledge—are to do their work properly, they have to know how to impart to others the knowledge which they possess. The art of teaching is not necessarily one possessed by those who have the knowledge; and with the assistance of the Board of Education a course of training for teachers is being instituted this summer. We have, I think, throughout the industry, and shall have in increasing numbers, a large body of very enthusiastic students—students who seek education and ensue it, not merely for the material advancement it will ensure them, not merely for the added value it will give them as wage and salary earners, but for the added value it will give to life for them, the widened and deepened interest in all their work, the broadened outlook of mind and the added confidence and sense of mastery of their job that make for the serenity of mind and sureness of judgment that mark the master minds in all professions and all industries.

These students realize the value of education as an end as well as a means, and we want also enthusiastic employers who realize the value of education for their employees not only as an instrument for improving their direct earning power as craftsmen or technicians, or salesmen or administrators because of their increased knowledge, but as a powerful influence in strengthening and developing character through the self-sacrifice and self-discipline it entails, and the habits of study and thought it creates and strengthens. If the employers will realize that education is a duty to the undertaking and to the employees, and will think not only of the employee but of the man, I believe the Education Scheme as submitted to you to-day will be a very real instrument of progress for the industry in the future. I have pleasure, therefore, in moving that the Annual Report of the Advisory Committee on Education, and the Special Report on the proposed revision of the Regulations of the Education Scheme be approved and adopted.

Mr. SAMUEL TAGG (Preston): I have pleasure in seconding the resolution submitted by the Chairman of the Advisory Committee. I do not propose to say anything on the recommendations contained in the Special Report and the modifications which are proposed, because, as you have heard, these are based on the experience gained in working the Scheme and on the suggestions emanating from the Junior Associations with the object of making the Scheme more useful; but I do want to say one word as to the position which we assume will come about as soon as the new Regulations are adopted. I do not think I have served on any Committee on which the other members have displayed such continued zeal, interest, and ability in the affairs of the Committee as have the members of the Education Advisory Committee. They have devised, launched, and up to the present time have run such a scheme; but I think the time has arrived when we, as engineers, should pull our weight, and assist in increasing facilities and extending the usefulness of the Scheme. One of the means by which we can do this is through the proposed District Committees which it is intended should be set up. These, as the Scheme provides, consist of members of the Junior Associations, as well as representatives of the District Associations; and I am sure that if care is taken in the selection of these Committees to include people who are really interested in the question, and are prepared to work, there is a great deal of useful work which they can accomplish. I commend this to the District Associations with every confidence that it will be taken up, because the members of the Institution and of the District Associations are anxious to advance the efficiency of the industry by improving the education of its technical officers—and, incidentally, there is no surer way of raising the general status of such officers. I have pleasure in seconding the adoption of the report.

Discussion.

Mr. JAMES BRIDGE (Elland): As I have the honour to represent the Junior Gas Associations on the Advisory Committee, on their behalf I have very great pleasure in supporting the adoption of the Report as presented by the Chairman of the Committee. I can assure you that the Junior Associations will do all they possibly can to make the scheme a success, and they will give it their very active support; but might I suggest that the success of the scheme can be assured by the assistance and support of every undertaking? It does not rest solely, or even largely, with the Junior Associations; it rests on the shoulders of each undertaking and also the engineers of those undertakings. There are many cases where students find it difficult to attend the technical schools on two and three evenings a week; and if the undertakings will give a little assistance in the way of leave, or in the matter of expenses, I am sure the Juniors will respond right loyally. While I am supporting the motion, might I, on behalf of the Juniors, express our thanks and appreciation to Mr. Goodenough, the Chairman of the Committee, for the strenuous work which he has put into this Scheme—work for which we are very grateful; and at the same time may I express our thanks to the other members of the Committee, and also to the members of the Board of Education?

The PRESIDENT: I think you will all agree with me that the Report represents a very large amount of work indeed; and I am sure you will wish, in due course, to accord your sincere thanks to Mr. Goodenough and his colleagues on the Committee. The Report is now open for discussion; and I need not remind you that Mr. Goodenough and his colleagues are particularly desirous of having criticism as long as it is constructive. They desire criticism in order to enable them to evolve what they think will be the very best possible scheme in the interests of everyone concerned. I do not intend to take part in the discussion, except respectfully to put a point to Mr. Goodenough, who has been speaking to us of character and determination, and gave us the printing trade as an example to follow. I have been told that the printing trade in London never works on Saturdays; that is an example which we are not going to follow. [Laughter.] The gas industry cannot afford to work only five days a week. We are a six days a week industry. [A voice: Seven days.]

The PRESIDENT: Let me finish! [Laughter.] We are a six days a week industry, with ordinary time, so far as we are concerned, for the seventh day, Sunday. Now I would like to get ahead; and if any would like to speak on the Report, we shall be pleased to hear them.

Mr. H. D. MADDEN (Cardiff): I should like to say a word in strong support of this Education Scheme, because I have seen something of the Scheme at work, not only in the Committee which has been redrafting the syllabus, but as Chairman of the Board of Examiners. We examiners have another aspect of the question; and I do feel this. Appeals have been made asking the members and their undertakings to give facilities to their staffs and the Juniors to attend the classes. I feel that is one of the greatest strengths we can have, because we can see, in examining the papers, where the strengths and the weaknesses are; and it will be possible to remedy some of the weaknesses if you will only be sympathetic and encourage the Juniors and give them the necessary facilities so that they can attend the classes and get the science subjects. So far as the Scheme has been working, it has appeared to us that there is a great weakness in the scientific cognate subjects as we get on to the Diploma stage. The Examiners realize that the Diploma men are put through a very stiff examination, and they have to have a deep knowledge of chemistry, physics, and engineering, which they have to take as subjects collateral with gas engineering. I should like also to put before the meeting the views of the examining body. I know that too often we are looked upon as inquisitors or as

the Grand Inquisition; but I would like it to go out that we are not. We are the friends of the students. ["Hear, hear."] Our duty is to try to find out where the student has benefited by the training he has received. In fact, if there is any doubt, the benefit of that doubt is always given to the student. I can cite you a case where the questions have not been quite finished. We can see from the evidence of the partly finished questions whether the student knows his subject; and he has not failed on that account. If he falls slightly short, the general tenor of his paper and his knowledge are taken into consideration, and we extend every sympathy. In regard to the ordinary grade student, I would like to point out that we realize it is the third-year stage, and that gas engineering is only one-third of the subject. We take that into consideration, because you cannot expect these students to have a great knowledge of gas engineering in the third year, when they are taking chemistry, physics, mathematics, and other subjects. Human nature is such that they cannot do it, and you cannot expect it; and in marking the ordinary grade the Examiners are very sympathetic to the student, realizing the fact that many subjects are being taken. When you come to the higher grade, I would like to give a word of warning. We look upon the higher grade as the filtering process. There is a first-class and a second-class pass, and it is only the first-class passes that can go forward for the Diploma; and I might say here and now that we jealously guard the passes into the first class. We want to feel sure that if you have a junior or an assistant coming to you, you may be sure—if he comes with a first-class higher grade—that he has won his spurs. We know the obligation you put upon us with regard to the Diploma stage; and we feel we must jealously guard awarding the Diploma because of the confidence which you impose upon us. You may therefore be quite certain that the man who has it knows his job. We do not say we can tell you his moral strength, his character, or his health; but we do say that he knows his job. With regard to the thesis, that matter was brought up at the Council meeting yesterday, and I think an improvement has been made. Up to now, in the gas engineering thesis, we have left to the student to send in a thesis. I am sorry to say, however, that in some cases some of the articles have not been theses. That was a weakness which was apparent, and it was brought before the Council yesterday and rectified. This year three or four subjects will be put out as acceptable for theses—on the same lines as are adopted by the Institution of Civil Engineers—so that the student may take any one of the four subjects, or, if he so desires, can put-in his own thesis on original work. I think that will be to the benefit of all those who are taking the Diploma course. In conclusion, I should like to say that the Examiners are very sympathetic, and want to see the Scheme a very great success, because we feel that the future of the industry largely depends upon it.

Mr. W. CLARK JACKSON (Neath): I simply rise to put-in a plea for the student engaged at a municipal gas-works. These students are barred, as far as I am aware, from any assistance financially, or even in the way of getting time off to attend the necessary classes. I have tried indirectly and directly to get help in that respect, but have found it impossible owing to the regulations of the Ministry of Health with regard to payments. I should therefore like to ask if the Committee can approach the Ministry, through the Board of Education probably, with a view to Gas Committees being allowed a certain amount of discretionary power in allowing the necessary time off to their student apprentices and student gas engineers, together with some financial assistance, to enable them to attend the necessary classes—that is to say, where works are some distance from the technical colleges. I should be glad if the Chairman of the Committee could assist in this matter.

Mr. J. P. LEATHER: I do not know whether anybody is going to answer that, because it is a misapprehension.

The CHAIRMAN: I wish you would, Mr. Leather.

Mr. LEATHER: It is quite a mistake to say that a municipality cannot give assistance to gas-works students. I am not connected with a municipality now, but I have been for a great number of years, and we certainly gave assistance—though not as much as I should advocate now. But we always paid their fees for the classes; and no doubt some municipalities would be prepared to do very much more now. There is no law against it.

Mr. JACKSON: Where the Corporation has the control of its own finances and has its own elective auditors, it can do this; but where it happens to be a rural district council or an urban district council or Corporation which has allowed itself to come under the Ministry of Health audit, then you find the circumstances I have put before you this morning. They are not allowed to spend money in this way or to give the necessary time off.

The PRESIDENT: Thank you. A note will be made of that point.

Mr. H. H. GRACIE (Edinburgh): I should like to say a word in support of what Mr. Leather has said as regards the suggestion that municipalities are not in favour of this Scheme. They are; and my Committee have taken the matter very seriously and sympathetically, have allowed students time on, have paid their fees and their wages while attending the classes, and have also provided them with books. All they ask is that they make satisfactory progress, and return the books to the library at the end of the session.

Mr. BERNARD KELHAM (late of Perth, Australia): I am a stranger at these meetings; but the point I want to raise is that the man living in Australia has no facilities for taking any examination under this Scheme, or even to attend classes. I have known men who have taken degrees at Universities, but who have been totally unable to take any examination in gas engineering. I have had quite a few young men come to me in Australia and ask for facilities for training, so that they could take the English examination in gas engineering; but I have not been able to help them. Therefore I think some means should be found for giving boys in different parts of the Empire opportunities for taking some examination in gas engineering.

Mr. GOODENOUGH: I have just been refreshing my memory by reference to Mr. Hole; and he tells me that we have had a student entered from Australia this year in gas engineering. He took his ancillary subjects in a technical institute in Australia, and there is no difficulty with regard to students in any part of the Empire, provided they can satisfy the Committee as to the instruction they have received in a suitable educational institution. With regard to the point raised by Mr. Jackson, we will certainly go into the matter with the Ministry of Health, and see if we can get some ruling which will be of assistance to the undertakings that come under the Ministry of Health audit. I would like to take this opportunity of paying a tribute to the work of the Examiners. They are not paid a very large amount for their work [Laughter]; in fact, I believe it is described as zero. The work is given as a labour of love to the industry and to the rising generation, and it is done with the greatest care and with the greatest enthusiasm on the part of the Examiners. As the Chairman of the Board of Examiners—Mr. Madden—indicated to you just now, what they desire is to assist the student while maintaining the standard; and I should not like to miss this opportunity, on behalf of the Committee and the students and the industry as a whole, of expressing our indebtedness to the Board of Examiners and, may I also say, to the teachers, because while they are paid fees in respect of their work, these fees are far from adequate to repay them for the work they put into their teaching. Therefore, I should like the Institution to express its indebtedness not only to the Examiners but also to the teachers who have helped to give this Scheme the success it has so far achieved. They will, I am sure, help to make it a still greater success in the future. As Mr. Madden has said, what the Examiners are out for is to make sure that the men who are certified by them know their job—not that they can merely answer questions by swatting up their books, but that they really do know their job. So that when you see a first-class certificate in gas engineering or supply in the higher grade, or the Diploma, you know that it really means something, and something considerable, and you can give a man a job straight away, with confidence that his education has fitted him for it.

The PRESIDENT: I now put the motion that the Report of the Education Committee for the year and the Special Report be adopted.

The Reports were unanimously adopted.

SEVENTEENTH REPORT OF THE RESEARCH SUB-COMMITTEE OF THE GAS INVESTIGATION COMMITTEE OF THE INSTITUTION OF GAS ENGINEERS.

EXAMINATION OF PRODUCTS OF COMBUSTION FROM TYPICAL GAS APPLIANCES.

PART II.—GAS FIRES.

Adopted by the Gas Investigation Committee, May 20, 1927.

RESEARCH SUB-COMMITTEE.

Chairman: Emeritus Professor Arthur Smithells, C.M.G., D.Sc., F.R.S., Director of the Salters' Institute, Pres.I.C.

Representatives of the University of Leeds: Professor J. W. Cobb, C.B.E., B.Sc., F.I.C. (Honorary Secretary), Emeritus Professor J. B. Cohen, Ph.D., D.Sc., F.R.S., Mr. G. R. Thompson, B.Sc.

Representatives of the Institution of Gas Engineers: Messrs. J. Bond, O.B.E., H. E. Copp, M.Inst.C.E., T. Glover, C.B.E., M.Inst.C.E., Thomas Hardie, M.Inst.C.E., S. Tagg, M.Inst.C.E., and C. Wood, O.B.E. Mr. C. S. Shapley was co-opted a member of the Research Sub-Committee for the purpose and period of research work at the Leeds Gas-Works.

Research Chemist: James W. Wood, M.Sc. (Tech.), A.I.C., in charge of investigations concerning the use of gas.

Research Assistant: G. B. Howarth, M.Sc., Gas Engineering (Leeds), A.I.C.

Research Chemist: A. Parker, D.Sc., F.I.C., M.I.Chem.E., in charge of investigations relating to the carbonization of coal.

Research Assistants: H. Kerr, A.I.C., Diploma Fuel and Metallurgy (Leeds), and C. B. Marson, Ph.D. (Leeds), M.Sc., A.I.C.

GENERAL INTRODUCTION TO THE SEVENTEENTH AND EIGHTEENTH REPORTS OF THE RESEARCH SUB-COMMITTEE.

The Gas Research Sub-Committee has continued its work during the past twelve months under the Chairmanship of Professor Smithells, and with the same membership excepting that Mr. H. E. Copp has taken the place, as an Institution representative, of Mr. H. Pooley, to whom the Committee would like to tender thanks for useful service. An alteration has been necessitated in the Research Staff by the appointment of Dr. Monkhouse to the position of Research Chemist to the newly formed Gas Liquor Effluents Research Committee. His place as a Research Assistant to the Committee was taken by Dr. C. B. Marson, who has just completed a two years' tenure of the Gas Research Fellowship.

The work of the Committee during the year has been of necessity somewhat hampered by conditions arising out of the prolonged coal strike, but readjustments were so made as to reduce this interference to a minimum, and substantial progress has been made in both the main branches of the Committee's investigations.

At the laboratory in the Leeds Meadow Lane Gas-Works, Mr. James W. Wood, assisted by Mr. G. B. Howarth, has been carrying out a thorough study of the conditions of production of carbon monoxide in the combustion of coal gas, using for the purpose in the first instance gas fires of modern and older pattern worked under various normal and abnormal conditions, and employing those refined methods for the determination of minute quantities of carbon monoxide which it had been necessary to work out in detail with great care during the preceding twelve months in order to obtain reliable results (Fifteenth Report). The results obtained are set out in the Seventeenth Report now presented and are summarized at the beginning of that report.

It may seem at first sight, having regard to the very small quantities of carbon monoxide produced by the modern gas fire under normal conditions of operation, and the fact that it is always used in conjunction with a flue, that the examination of this particular appliance has been carried out with a greater minuteness of observation and under a greater variety of conditions than was necessary, but it should be explained that the old and new gas fires together provided an excellent opportunity for studying experimentally the conditions of carbon monoxide production, and the influence of such factors as are brought into operation by altering the rate of gas supply, the degree of aeration, and the exposure of a solid to the flame, the solid in this case being the radiant of the fire. The difference between the new and the old fire is striking and suggests that careful study continues to be given to improvement in gas fire manufacture and design.

The second branch of the Committee's work has been a continuation of the studies in carbonization, of which some results were reported last year as showing the influence of the size of coal upon the progress of carbonization and the results obtained. This year the work has been extended by not only grading the coal in different sizes, but testing the results of admixture of different sizes, testing also the influence of adding coke breeze to the coal and of altering the temperature of the retort to a certain extent. The results would suggest the advisability of obtaining figures for temperatures considerably lower than those so far employed, and of determining what alteration would be brought about, particularly as regards the effect of breeze, if a much more fusible coal were employed.

Another set of experiments of special interest was made on the influence of adding certain inorganic constituents to coal before carbonization. It had been found by Marson and Cobb (see Gas Research Fellowship Report, 1926) that sodium carbonate, iron oxide and calcium carbonate had remarkable effects both on the structure of the coke and on its reactivity to steam and carbon dioxide when the carbonization was made on the laboratory scale. The experiments now carried out on a much larger scale made it possible to get results as to gas and thermal yields and the production of ammonia and sulphur compounds which had not been ascertained by the laboratory experiments. The results were interesting in disclosing that with the coal tested, and under its conditions of carbonization, the structure of the coke was not very obviously altered by admixture of sodium carbonate, iron oxide, and calcium carbonate in small quantity. The difference in this respect between the laboratory and larger scale results was not surprising, having regard to the nature of coke formation as dependent so largely upon the actual rate of evolution of gas from the fused mass. When, however, the cokes came to be tested, as they were tested by the Gas Research Fellow, it was found that their reactivities had been considerably heightened by the admixture of sodium carbonate, iron oxide, and lime. There had also been a marked influence in other directions, the results here being in agreement with those obtained on the laboratory scale. The special cokes produced contained increased quantities of sulphur, the sulphur in the gas being correspondingly lowered. The quantity of sulphuretted hydrogen in the crude gas was reduced to approximately half by the addition of the three compounds tried, and the yield of ammonia increased by over 30 p.ct. with the lime coke. The yields of gas and therms in the gas were also affected.

A number of tests has been made of the reactivities and ignition points of cokes made in experiments carried

out during the past two years, but it is believed advisable to complete these and issue the results in a separate report.

The Committee would like to express its thanks to the staff which has been responsible during the year for the carrying out of these investigations. Mr. Wood and Mr. Howarth dealt with the carbon monoxide work; Dr. Parker, assisted by Mr. Kerr and Dr. Marson, with the studies in carbonization. The results come directly from the care and skill which they have exercised.

Finally, too, the Committee would like to tender its thanks to Mr. Shapley and the Leeds Corporation Gas Department for the facilities which they have continued to grant at the Meadow Lane Gas-Works.

SUMMARY.

The investigation has for its object the examination of the products of combustion from typical gas appliances, operated under a variety of conditions, with special attention to certain constituents such as carbon monoxide, occurring in small quantities, but nevertheless of considerable importance as affecting the successful utilization of gas.

The work was commenced by the development and critical examination of the iodine pentoxide method for the determination of small quantities of carbon monoxide, the results being presented last year in the Fifteenth Report. This method has been further investigated, the most important modification being the adoption of a uniform granular iodine pentoxide of 30—50 mesh I.M.M.* for filling the reaction tubes. This has resulted in a reduced resistance in the tubes and an increased rate of working, and has also enabled iodine pentoxide "blanks" of less than 1 part of CO per million to be obtained. (See Section VI.)

The present report is devoted to the examination of the products of combustion from two gas fires when operated in a normal manner, and to special experiments with them to determine some of the factors affecting carbon monoxide formation.

The fires were installed as in an ordinary house, in a room of 2615 c.ft. capacity, being connected to a brickwork flue, 10¼ in. by 15¼ in. by 38 ft. high. Gas of calorific value 470 B.Th.U. gross per c.ft. was used, and 2000 B.Th.U. per radiant per hour was regarded as the normal gas consumption for the fires. Systematic tests at different gas rates and with different degrees of aeration were made at rates up to 30 p.ct. in excess of the rated capacity of the fires. For convenience in testing, a damper was placed in the chimney to restrict the flow of air up the flue to 4000-6000 c.ft. per hour, but the method of stating the results is such that they are independent of the ventilation. Without the damper, ventilation of 9000-10,000 c.ft. per hour was obtainable at the normal gas rate.

In stating results, prominence has been given to the *amount of CO produced per unit of gas burned* (expressed for convenience in parts of CO per 10,000 of gas burned) rather than to the concentration of CO in the gases leaving the appliance. The concentration of CO in the theoretical products of combustion is approximately one-fourth the above quantity, while the concentration of the CO in the flue gases or chimney gases depends upon the degree of ventilation, and in our experiments was from one-fiftieth to one-two hundred and fiftieth of the value shown per 10,000 of gas burned.

GAS FIRE "A" (NORMAL AERATION).

The fire used was a typical modern 9-radiant duplex fire adjusted as nearly as possible in accordance with the makers' instructions and taking the normal gas consumption of 38·3 c.ft. per hour of 470 B.Th.U. gas with a pressure of 1·6 in. water gauge. (Air-gas ratio 1·48 = 38·2 p.ct. of theoretical air requirement of gas.)

The CO_2 in the chimney gases as sampled was less than 0·5 p.ct. and the CO less than 1 part per 10,000 in these tests. At half the normal gas rate the production of CO was 15 parts per 10,000 of gas supplied to the fire, rising gradually to 30 parts per 10,000 at the normal gas rate. Above this rate flames were projected through the radiants, and the CO production rose very rapidly to 200 parts per 10,000 of gas burned (*i.e.*, 2 p.ct. of the gas burned) at 5·5 c.ft. per radiant per hour. The hourly production of CO at the normal gas rate was 0·12 c.ft.

GAS FIRE "A" (HIGH AERATION).

The primary air-gas ratio of the fire was increased from 1·48 to 1·90 by readjusting the gas nipple and working at a higher pressure, 2·7 in. w.g. being required for the normal gas delivery. The flames were smaller than before, with well-marked inner cones, but on the whole the fire was not so satisfactory as with the former adjustment.

With the higher degree of aeration the production of CO was diminished, being 16 parts of CO per 10,000 parts of gas burned at the normal gas rate, while the highest CO production observed was less than 50 parts per 10,000 of gas burned with a 25 p.ct. overload on the fire.

GAS FIRE "B" (LOW AERATION).

The fire used was the 10-radiant fire (date 1911) which had been used for the aeration experiments of the Eleventh Report. The radiants originally supplied with the fire were used for the tests. The normal gas rate (2000 B.Th.U. per radiant per hour = 42·6 c.ft. per hour of 470 B.Th.U. gas) was obtained with 2·4 in. w.g. The fire was adjusted to give "soft" flames. (Air-gas ratio 1·38 = 35·6 p.ct. of theoretical air requirement of gas.)

At half the normal gas rate the CO production was practically the same as for gas fire "A," 16 parts per 10,000 of gas burned; but it increased somewhat rapidly as the gas rate increased, until 235 parts per 10,000 of gas burned was reached at the normal gas rate. Flames were projected through the radiants at gas rates well below the normal, and the CO production was at its maximum at the normal gas rate. When the gas rate was further increased, flames were permanently established above the radiants and the CO production fell to 209 parts per 10,000 of gas at 5 c.ft. per radiant per hour. The production of CO at the normal gas rate was 0·98 c.ft. per hour.

GAS FIRE "B" (HIGH AERATION).

The aeration of the fire was increased to the highest permissible degree by opening the air slide, and the inner cones of the flames became rough and the fire very noisy. The air-gas ratio was then 1·87, or 48·6 p.ct. of the theoretical air requirement of the gas.

The increased primary aeration resulted in the reduction of the *maximum* CO production to about half the value given in the low aeration tests. At half the normal gas rate the CO production was 7 parts per 10,000 of gas burned, rising gradually to 80 parts per 10,000 at the normal rate, or only about one-third the amount with the lower degree of aeration, equivalent to an hourly CO production of 0·34 c.ft. Flames did not appear above the radiants until the normal gas rate had been exceeded, and a maximum CO production of 100 parts per 10,000 of gas (*i.e.*, 1 p.ct.) was observed just beyond the normal gas rate.

The principal results obtained for the two fires as they would ordinarily be adjusted are summarized in the following table.

—	Air-Gas Ratio.	CO Produced in Parts per 10,000 of Gas Burned.			
		Half Normal Gas Rate.	Three-Quarters Normal Gas Rate.	Normal Gas Rate.*	Maximum CO Observed.
GAS FIRE "A" (modern type)—					
Normal aeration . . .	1·48	15	18	30	200
Increased aeration . . .	1·90	..	13	16	47
GAS FIRE "B" (pre-war model)—					
Low aeration (soft flames)	1·38	16	65	235	235
High aeration (noisy flames)	1·87	7	16	80	102

* Normal gas rate, 2000 B Th.U. per radiant per hour. 470 B.Th.U. gas used for tests.

From the above figures it is evident that the thermal losses due to unburned CO in the flue gases were of little consequence. The concentration of CO in the flue gases is largely dependent upon the extent to which the products of combustion are diluted by ventilation; and in the above

* The standard laboratory sieves of the Institute of Mining and Metallurgy, in which the mesh number is the number of wires per inch, and wires and spaces are of equal width.

experiments the highest concentration recorded was only 2 parts per 10,000, and many of the tests showed only a fraction of a part per 10,000. The concentration of CO in the flue gases can be readily calculated for any assumed degree of ventilation, from a knowledge of the gas rate and the production of CO per unit of gas burned.

Although the amount of CO produced per unit of gas burned is small, the *total* amount of CO produced when the gas consumption is taken into account may not be negligible: there may be sufficient CO produced to justify the continuation of what is already regarded as good practice—namely, *that all such fires should communicate with efficient flues.*

When the degree of primary aeration was increased, there was a marked reduction in the amount of CO produced for both the fires examined.

The smaller CO production found for the modern gas fire "A" would be consistent with a greater uniformity in quality and in rate of discharge of its primary air-gas mixture, as indicated by the greater steadiness of its flames, although so far as CO production alone is concerned, its radiants were somewhat inferior to the older type.

It may be useful to note that a comparison of these data with others obtained in work carried out by Bligh and Hodsman at the University of Leeds on coal and coke fires, shows that in typical cases the thermal wastage from CO production is much higher with a solid fuel fire than with a properly adjusted gas fire.

DETAILED ACCOUNT OF INVESTIGATIONS.

Research Chemist: JAMES W. WOOD.

Research Assistant: GILBERT B. HOWARTH.

INTRODUCTION.

The programme of research work approved by the Gas Investigation Committee had for its object the collection of reliable data respecting the nature of the products of combustion from typical gas appliances, and was directed more especially towards constituents such as carbon monoxide, which, although occurring in small quantities, nevertheless demand serious consideration.

The Fifteenth Report (1926) of the Gas Investigation Committee gave a complete account of the iodine pentoxide method which we had developed for the exact determination of carbon monoxide at low concentrations. A scheme of work was drawn up commencing with the examination of the products of combustion from gas fires; but on account of the unusual variations in gas quality and reduction in pressure consequent upon the coal strike of 1926, reliable systematic comparisons could not be continued. Attention was therefore diverted for a time to the investigation of some minor difficulties associated with the method we had adopted for the determination of CO, and the clearing of certain points in which our opinions differed from those of other workers in the same field.

As a result of these investigations, which are outlined in Section VI. of the present report, we are using a uniform granular iodine pentoxide of a definite size (as we proposed in the Fifteenth Report) and are now able to obtain consistently lower "blanks" than those indicated in the Fifteenth Report. The latest blanks are equivalent to less than 1 part of CO per million parts of sample. The treatment necessary to maintain the reagent in proper working condition has been further studied and it has been possible to increase the rate of working. We have, however, not found it necessary to make any essential alteration to the apparatus or procedure described in the Fifteenth Report, although a few details have been modified.

Upon the resumption of normal conditions of gas supply, attention was again turned to gas fires. As gas fires are usually connected to flues, the examination of the products of combustion for unburned constituents is more important in its relation to the general problem of attaining efficient gaseous combustion and to obtaining an accurate thermal balance for the gas fire, than with regard to the possible toxic properties of the gases; while information as to the ventilation effected is also of interest.

The examination of the products of combustion from gas fires for carbon monoxide and sulphur compounds formed part of an extensive programme carried out by E. W. Smith for the Gas Heating Research Committee of the Institution of Gas Engineers in the years 1908-11.

In the summary of the First Report of that Committee the following statement referring to gas fires appears:

> "2.—No carbon monoxide escapes under ordinary conditions into the room, and very little is ever found in the flue."

The methods used for the determination of carbon monoxide at the time the above tests were conducted (1908-9) were neither so sensitive nor so exact as those available to-day. While, therefore, Dr. Smith's work established the important point that the flue losses due to carbon monoxide were inconsiderable, it is evident from the results of other workers that the amount of carbon monoxide produced by the gas fires of that period was probably under-estimated. Further, the changes in gas fire design which have taken place during the intervening years provide additional reasons for a re-examination of this matter, using appliances of the latest type.

We examined two gas fires, and soon found that the production of CO varied over a relatively wide range in circumstances that might be regarded as being those of "ordinary use," and that its formation was influenced by a number of factors, any one of which might predominate in a particular case and render very hazardous a forecast of the final result.

As it was important that we should investigate the general conditions which favoured the formation of large or small proportions of CO, rather than the CO output of particular fires only, under normal conditions of use, it became necessary to extend the work and make far more tests upon gas fires than was originally contemplated. It is believed that we can demonstrate that there has been a considerable advance in gas fire design, and that we can indicate wherein the improvement lies. The principal factors investigated have been the type of fire, the type of radiant, the degree of aeration, and the gas rate.

Some necessary preliminary work in connection with the examination of products of combustion from ring burners and lighting burners has also been carried out.

SECTION I.

PLACE AND GENERAL CONDITIONS OF TESTING.

The results obtained during gas fire tests may be very much influenced by the manner in which the fire is installed; hence the design and erection of a special

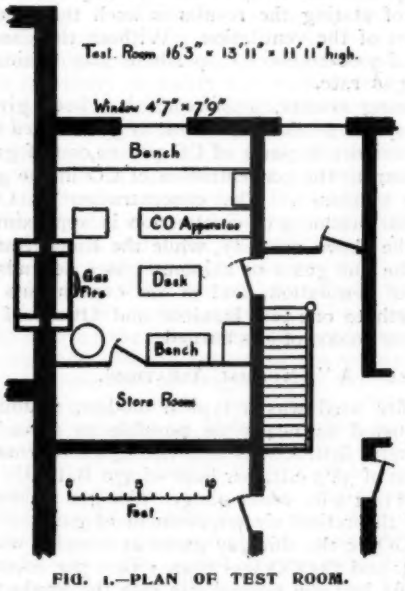

FIG. 1.—PLAN OF TEST ROOM.

chamber to secure standardized and controllable conditions during the ventilation experiments undertaken by the Ventilation Research Committee of the Institution of Gas Engineers. (First and Second Reports of Ventilation Research Committee, 1914 and 1915.)

In the present experiments, however, this chamber was not used, but the gas fires were tested in the room placed

at our disposal at the Meadow Lane Gas-Works, Leeds. This room was on a first floor and was formerly part of the residence of the Works Engineer. It may therefore be regarded as a typical domestic installation (see fig. 1).

The room was 22 ft. by 14 ft. by 12 ft. high, and with allowance for chimney breast and furniture had a capacity of 3540 c.ft. A portion of this was cut off by a light partition to form our store-room, reducing the capacity of the apartment containing the fire to 2615 c.ft. The walls were plastered in the usual way and had been painted; the floor was constructed of ⅜ in. tongued and grooved boards.

The principal air inlets to the room were provided by the window and the usual crevices round the door. The window was very large and the lower sash was raised some 6½ in. by means of a board. The upper sash was closed, and it is estimated that the air inlet between the two sashes (7 ft. above floor level) had an effective area of 50 sq. in. Beading was placed round the door jambs to improve the fit, but there is evidence that a considerable proportion of the air reaching the room came by this route from the lower parts of the building.

The brickwork flue from the fireplace to which the gas fires were fitted was of a size commonly used for coal fires and had an actual cross-section of 160 sq. in. (10¼ by 15½ in.) The stack containing this flue was rather lofty, being 38 ft. from floor level to the top of the chimney pot. Details of the manner of installing the fires themselves are given for each fire tested.

Much of the technical difficulty of examination lies in the small amounts of CO produced and the great dilution to which the products are subjected by ventilation. With the exception of tests specially noted, all results were obtained with a loosely-fitting damper placed in the brickwork flue, 16 ft. above floor-level. The ventilation was thereby restricted to 4000-6000 c.ft per hour, with 0·2 to 0·5 p.ct. as typical values for CO_2 in the chimney gases, and with dilution factors of 100 to 200. The air of the room was thus changed about twice per hour, and this was regarded as a satisfactory compromise, as although for ease in testing we should have preferred lower dilution factors, we wished to interfere as little as possible with the normal operation of the fire, and moreover, desired that there should be no suspicion of CO production because of unduly restricted draught on the fire. It will be noted that in these tests with gas fires an accuracy of 1 part per million in the determination of the CO in the flue gases is necessary in order to be able to report the CO per unit of gas burned to 1 part in 10,000, when the dilution factor is 100.

A sampling tube was inserted in the chimney 5 ft. below the damper and 11 ft. above floor level, where it might be considered that the products of combustion were reasonably well mixed. This tube was joined by a very short connection to a special vessel (Fifteenth Report, fig. 2, Type I) filled with coarse calcium chloride, and then by a length of glass tubing fused into one piece (⅛ in. bore by 26 ft. long) to the trains of apparatus for the determination of CO and CO_2. A second sampling tube terminated 9 in. in front of the fire at a slightly lower level than the edge of the canopy. This led to a second train of apparatus for the determination of CO and CO_2. By this means a test of the air near the fire was made simultaneously with that on the products at the upper sampling point and of equal duration. In the case of the better appliances the correction to be made for CO and CO_2 in the air entering the flue or chimney is very important, and may account for two-thirds of the CO found at the upper sampling point. (See Section VI, 1.)

The duration of a test was, as far as possible, governed by the considerations outlined on pp. 122-124* of the Fifteenth Report for obtaining reasonably accurate measurements of the CO and CO_2 in the flue gases. In most of the cases this involved running overnight and dealing with 17 to 20 litres of products of combustion in about 16 hours. This was not always practicable, as the minimum overnight pressure on the town supply, when reduced by the back-pressure necessary to operate the regular meter, a governor, and an additional test meter, would not permit the higher gas rates being maintained. In such cases tests of 5 or 6 hours duration were made in the daytime at a sampling rate of 2 to 2½ litres per hour; and where tests of shorter duration were adequate the gas was drawn from a 200 c.ft. experimental holder, loaded to give the necessary pressure. The above periods do not include the times required for preliminary and final sweeping of the trains.

The gas was supplied to the fires through a 1 in. mercurial governor and 10-light wet meter, and a pressure recorder was used to be certain that the desired conditions had been maintained throughout the test. In all cases the gas cock on the appliance was fully open, the gas was controlled by the governor and by a graduated cock on outlet meter; and in accordance with our usual practice the pressures given are those taken close to the appliance when operating at the specified rate.

Partly as a matter of experience and partly on the basis of makers' recommendations, we accepted 2000 B.Th.U. per radiant per hour as a basis for the preliminary adjustment of each fire.

At first it was considered sufficient if the gas rates were known approximately (*i.e.*, within 2 or 3 p.ct.), but when the peculiar shape of the gas-rate—CO-production curves was discovered, it was plain that the gas-rate should be defined with precision. Considerable work was, therefore, entailed not only in calibrating the meter, but in balancing the drum, and in determining the overdriving error at different rates. It was also necessary to correct for the evaporation of water from the meter, which would frequently correspond with a change in capacity of 0·5 p.ct. in the course of a test; the meter being kept in a warm room and as much as 500 c.ft. of gas being passed through it. The meter was suitably placed and provided with shields to protect it from radiation from the fire.

In all cases the fire was run under the specified conditions for a sufficient period to attain a steady state; and within an hour of starting and during the test no other gas appliance was used in the room, which served the dual purpose of test room and laboratory.

The tests were made in groups at suitably selected gas rates, each group corresponding with a particular setting of the air regulator. In view of the unimportant change in air-gas ratio with gas rate indicated in our Eleventh Report, it was considered sufficient to determine the degree of aeration corresponding to each setting of the air regulator at or near the normal gas rate only.

The gas used for the tests was drawn from the town supply and approximated to 470 B.Th.U. (gross) per c.ft. at 60° Fahr. and 30 in. bar., the nitrogen ranging from 10 to 13 p.ct. According to prevailing conditions the gas was a mixture from one or more of three different types of vertical settings, with varying proportions of coke-oven gas and water gas. Within the limits imposed by the small range of calorific value variation, the composition of the gas has therefore been subject to such changes as are likely to take place in ordinary gas-works practice. As, however, other conditions such as type of fire, type of radiant, degree of aeration, and gas rate have been simultaneously varied, it is impossible to say as yet whether there is any relation between the composition of the gas burned and the amount of CO produced. This can only be decided by experiments specially directed to the elucidation of that point.

Complete analyses of all the gases used in these tests could not have been made without interfering unduly with the main tests, but the following data may be taken as representing the principal characteristics of the gas used.

Composition—CO_2	4·0
O_2	0·6
C_mH_n	2·1
CO	15·1
H_2	46·4
CH_4	21·4
N_2	10·4
	100·0

Calorific Value Calculated from above Analysis.	465 B.Th.U. (Gross) at 60° Fahr., 30 in. bar. (Wet).	
Sp. gr. of gas (dry air = 1·00)	0·487	
Air required for complete combustion	3·88	c.ft. per c.ft. of gas.
Vol. of prods. of combustion—Water as vapour	4·58	
Vol. of prods. of combustion—Water condensed	3·63	
CO_2 produced by combustion of gas	0·462	

In all, some 70 tests have been made upon two gas fires. They are not reported in chronological order, but are

* Transactions of the Institution of Gas Engineers, 1925-26.

grouped so as to bring out the principal points of interest or importance.

METHOD OF STATING RESULTS.

The principal data obtained from the experimental work are summarized in Tables I. and II. and figs. 6, 7, and 8 appended, and the following explanations should make the entries clear.

Gas Rate.—Cols. 2, 3, and 4.—The rate given in Col. 2 is the observed gas rate reduced to standard conditions—viz., 60° Fahr. and 30 in. bar (wet). In comparing fires which are of the same general type but of different sizes, especially when the difference is principally in the number of radiants used, comparison is facilitated by considering the gas rate and CO production *per radiant*. As the two fires examined were of different sizes, Col. 3 has been inserted to show the gas consumption per radiant per hour. If gases of considerably different calorific values had been used in the tests, the advisability of making comparisons on a thermal basis and including columns to show the thermal equivalents of Cols. 2 and 3 would have required consideration, but for the small range of calorific values covered in these tests it is not necessary. As already explained, the normal gas rate for each fire was arbitrarily, but with some justification, placed at 2000 B.Th.U. per radiant per hour, and this is the basis of comparison in Col. 4.

Gas Pressure.—Col. 5.—This shows the pressure in tenths of an inch water gauge at which the fire was worked, and was taken close to the appliance when working at the specified rate.

Volumes of Samples.—Col. 6.—In almost every case tests were made simultaneously upon the air and the chimney gases, and the volumes of the samples used were accurately measured and reduced to standard conditions of temperature and pressure. The two samples were of approximately equal volumes, and a single value is inserted in the table for each pair of tests to give some idea of the size of sample operated upon.

CO_2 from Gas.—Col. 7.—This is a measure of the total carbon content of the gas supplied to the fire, determined by combustion of a sample of the gas over copper oxide in the modified Bone and Wheeler gas analysis apparatus.

Carbon Monoxide.—Cols. 8 and 9.—These figures show the concentration of CO in the air of the test room and in the chimney gases as they actually existed during the tests. It it necessary to determine these quantities but they are by themselves of little service for judging the behaviour of the appliance. It is obvious that these figures are influenced not only by the output of CO per unit of gas burned, but also by the total amount of gas burned and the degree of ventilation during the test. The entries in Col. 10 are explained more fully in Section VI, 1; but by deducting CO found in the air at the lower sampling point from that found in the chimney gases at the upper sampling point we obtain a correct measure of rate of CO production.

Carbon Dioxide.—Cols. 11, 12, and 13 are corresponding data for CO_2, and the CO and CO_2 were determined in the same samples of chimney gases and air respectively.

Ratio CO/CO_2 p.ct.—Col. 14.—This figure is inserted as a rough estimate of the proportion of carbon wasted in the form of CO in the flue gases. It must not, however, be assumed that this necessarily represents the whole of the unburned matter in the products of combustion.

Dilution Factor.—Col. 15.—The dilution factor indicates the volume of products of combustion and excess air (reduced to 60° Fahr. and 30 in. bar.) per c.ft. of gas burned. The expression from which it is derived is given in Section VI, 1.

Ventilation.—Col. 16.—This is the product of gas rate and dilution factor, and indicates the volume of air passing up the chimney per hour.

Carbon Monoxide Produced.—Cols. 17, 18, and 19.—It has already been shown that it is difficult to interpret directly the carbon monoxide figures in Cols. 9 and 10. If, however, we multiply the values in Col. 10 by the dilution factor in Col. 15, we obtain a fundamental quantity—the amount of CO produced per 10,000 parts of gas burned—which is independent of peculiarities of sampling or of ventilation. This product is given in Col. 17. It represents the proportion of the gas passing away unburned as carbon monoxide in the flue gases, and is some indication of the efficiency of combustion. When considering appliances such as gas rings and lighting burners, which discharge their products of combustion directly into the air of the room and not into a chimney, the rate of CO production by the appliance is important. For the sake of uniformity we have, therefore, inserted the hourly production of CO by the two fires tested, both for the complete fire and per radiant (Cols. 18 and 19).

It is not convenient to reproduce figs. 6, 7, and 8 in a manner that will permit the CO values to be read directly from them, especially in the case of the lower values. We have, therefore, in Table II. given a selection of CO figures for certain gas consumptions per radiant per hour, these having been read from the original diagrams plotted on a sufficiently large scale for the purpose.

ALTERNATIVE METHODS OF STATING RESULTS.

It will be observed that, while information has been given respecting the rate of CO production per unit of gas burned, and also respecting the *total* rate of CO production, little stress has been placed upon the *concentration* of CO in the gases leaving the appliance. On account of the large and variable degree of dilution taking place with domestic appliances, it is almost impossible to make valid comparisons of different appliances or of the results obtained by different workers on the basis of figures such as those given in Cols. 8, 9, and 10 of Table I.

It has been proposed that as a uniform basis of comparison we should calculate the concentration of CO in the "theoretical products of combustion." This value can easily be obtained from Col. 17 by dividing by the volume of the theoretical products of combustion per unit of gas burned. For gas of the quality used in our tests, the divisor would be either 4·6 or 3·6, according to whether we assume that the water vapour produced during combustion remains as vapour or is condensed.

It will rarely happen that the construction of an appliance will permit a person near it to breathe products of combustion undiluted with extra air, and there is therefore serious objection to stating the concentration of CO in the theoretical products of combustion, on the ground that it exaggerates the possible risk of CO poisoning. It is plain that the concentration of CO in the products of combustion should be considered with respect to some suitable excess of air, but it is doubtful if any single value could be suggested that would be typical or would meet with general acceptance for this purpose.

It is also unwise to consider appliances only with respect to the concentration of CO in the products of combustion without some attention to the magnitude of the stream of products from them, and to constructional details which would determine whether or not a person near the appliance could be subjected to a mixture containing CO of the concentration prevailing at the sampling point.

SECTION II.

GAS FIRE "A" (MODERN FIRE).

INSTALLATION AND ADJUSTMENT.

The gas fire used for these tests was a typical 9-radiant duplex fire of recent design, and is shown in figs. 2 and 3. The fire was provided with two injectors, one supplying the central five burner nozzles and the other the two outer pairs of nozzles. There was no air-shutter, but the burner was fitted with multiple-orifice injectors, and the degree of aeration was controlled in each case by two internal caps or thimbles, one of which governed the number of orifices in action, and the other the pressure upon them. In the fully open position the two injectors had 28 and 22 orifices (0·032 in. dia.), and these could be reduced to 8 and 6 respectively by means of the adjusting caps. The burner nozzles (orifice dia. $\frac{7}{64}$ in.) were separate fittings pressed into holes in the castings and at their lower ends carried a plate of refractory material $\frac{1}{4}$ in. dia., and $\frac{1}{8}$ in. thick, perforated with numerous small holes. (109 holes, $\frac{2}{64}$ in. dia.) The use of these plates seems to result in very silent and steady flames, constituting one of the most important features of the fire. The radiants were of type "A" shown in fig. 5a, and will be discussed more fully later.

The fire was connected to the brickwork flue already described, in the following manner. The fireplace was closed with an iron sheet fitting into a recess in the casting and provided with a hole 13 in. by 8 in. (104 sq. in.).

The back of the gas fire framework was pressed firmly against this sheet, and the hole received the swivelling flue outlet pointing in a direction of about 60° to the horizontal; it also communicated directly with the auxiliary opening (under the canopy) provided for additional ventilation. The main flue outlet was of generous proportions (9⅞ in. by 2½ in., with semi-circular ends) having an area of 24 sq. in., while the auxiliary opening provided a further 12 sq. in. No cement or other

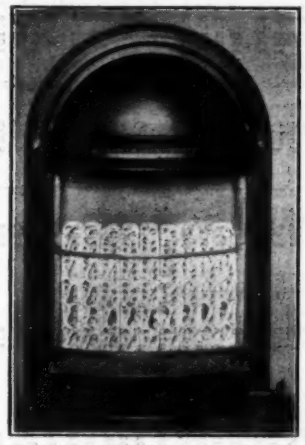

FIG. 2.—GAS FIRE "A."

packing was used between the gas fire casting and the iron sheet, or between the latter and the fireplace; but all joints were a reasonably good fit.

Adjustment of Fire.—In setting the fire for these tests we endeavoured to comply as closely as possible with the instruction card issued with the fire by the makers. In essence these instructions require that flames of a certain size and with certain characteristics shall be obtained *before the radiants are placed in position*, and assume that such adjustment can be made (at least approximately) for a certain thermal rate per radiant with any of the mixtures normally distributed as "town's gas" in this country. It is probable that a more satisfactory adjustment can be obtained in this way by semi-skilled workers

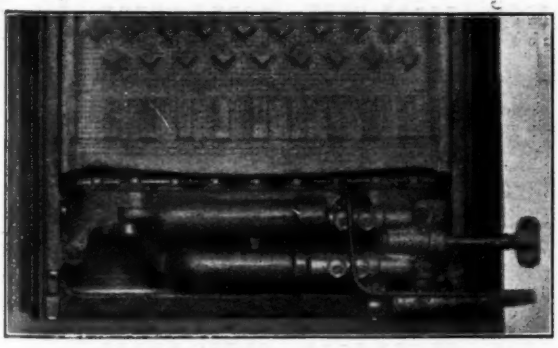

FIG. 3.—BURNER OF GAS FIRE "A."

than by attempting the more fundamental operation of fitting the flames to the radiants; and in practice the adjustment can be made more rapidly and the flame characteristics can be more accurately determined in the absence of the heat and glare from the radiants.

The adjustment is made in two stages. The first adjustment is for aeration, and demands that inner cones should be obtained two-thirds the length of the flames. We were unable to fulfil this condition. In the first place it is difficult to make a consistent estimate of the ratio of cone height to flame height, especially when the flame finishes with an ill-defined wisp or tail; and different observers may interpret the same condition very differently.

Starting with short well-marked greenish-blue inner cones (air-gas ratio for this fire and grade of gas about 2 : 1) we reduced the degree of aeration, and the cones lengthened, destroying the colour contrast, but still preserving a smooth outline to the cones, which were visible on close inspection. A cone-height half the height of the flames was the highest we could observe, since with further reduction in the degree of aeration we were unable to identify the upper limit of the inner cones. We therefore decided to test the fire in the state in which the inner cones were well-defined though they were only faintly visible and not more than two-fifths the length of the flames; while the flames would be described as "soft" there was no suggestion of luminosity; the air-gas ratio was about 1·5.

The second adjustment is for flame height; and 5 in. was recommended as a suitable adjustment, it being pointed out that this should correspond approximately with a thermal consumption of 2000 B.Th.U. per radiant per hour. Inspection of the results will show that these conditions could be obtained and the fire satisfactorily operated at quite low pressures.

As this was a 9-radiant fire and gas of 470 B.Th.U. gross per c.ft. was being used, the "normal" gas rate for the fire was 38·3 c.ft. per hour, or 4·26 c.ft. per radiant per hour. This gas consumption was sufficient to heat the radiants satisfactorily as high as the radiant clip, the portion above attaining a dull red heat and the fire being uniformly heated from side to side. Tests were not confined to the "normal" gas rate, but without altering any of the adjustments of the fire a complete series of tests was made at rates ranging from about half rate to a considerable overload on the fire.

RESULTS OF TESTS. GAS FIRE "A," GROUP 1. (NORMAL AERATION.)

The results of tests upon this fire are given in Table I. (Group 1) and in fig. 6 (see also Table II.). The flue gases for Tests 10, 11, and 12 were sampled from a tin cone 16 in. long attached to the main flue outlet. Special tests disclosed lack of homogeneity in the products of combustion after so short a travel, and the dilution factors are so high that the tests can only be regarded as approximate. The tin cone did not communicate with the auxiliary ventilation opening, and consequently the figure given in Col. 16 does not represent the whole ventilation of the room in these three tests.

An attempt was made in Tests 13 to 18 inclusive to reduce the experimental difficulties by inserting a damper in the chimney and sampling at a point further from the fire; and this arrangement was retained for the remainder of the tests. (Test 17 was made without the damper for a special purpose.)

In view of the results obtained from gas fire "B," it seemed desirable to return to gas fire "A" and repeat some of the determinations, at the same time extending the experiments to cover gas rates well above the normal. (Tests 60 to 65 inclusive.) The results are arranged in order of gas rate in Table I, and the two sets of tests are not differentiated.

The fire was silent at all gas rates, and with the setting we had adopted the inner cones were just distinguishable on careful inspection when the fire was burning with the radiants in position.

The recommended amount of gas for the fire (38·3 c.ft. per hour of 470 B.Th.U. gas) was delivered with a pressure of 1·6 in. w.g. at the inlet to the injector fitting. The

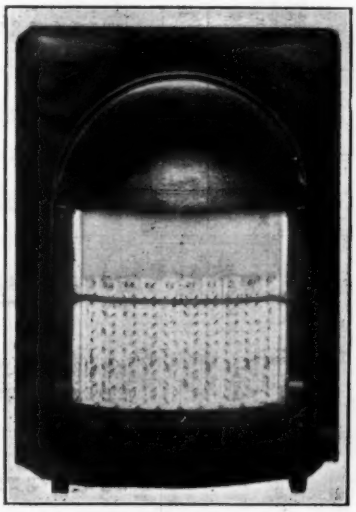

FIG. 4.—GAS FIRE "B."

TABLE I.—*Summarized Data for Gas Fire Tests.—Normal Operating Conditions.*

Test No.	Gas Rate. C.Ft per Hour. Total.	Gas Rate. C.Ft per Hour. Per Radiant.	P.Ct. Normal Rate.	Pressure, Tenths In. w.g.	Approximate Volumes of Samples, Litres.	CO_2 from Gas. P.Ct.	Carbon Monoxide, Parts per 10,000. As Sampled. Air.	As Sampled. Products.	Difference. (9)—(8)	Carbon Dioxide, P.Ct. As Sampled. Air.	As Sampled. Products.	Difference. (12)—(11)	Ratio. $\frac{CO}{CO_2}$ P.Ct. $= \frac{(10)}{(13)}$	Dilution Factor.	Ventilation up Flue, C.Ft. per Hour.	Carbon Monoxide Produced. Parts per 10,000 of Gas Burned.	C.Ft. per Hour.	C.Ft. per Radiant per Hour.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
GROUP 1.			GAS FIRE "A."		Air/Gas Ratio, 1·48.							Normal Gas Rate, 38·3 C.Ft. per Hour.						
11	18·54	2·06	48	5	17·3	46·4	0·189	0·223	0·034	0·038	0·125	0·087	0·4	533	9882*a*	18·1	0·034	0·0037
64	19·08	2·12	50	5	18·4	46·5	0·081	0·142	0·061	0·050*	0·2656	0·2156	0·3	215	4100	13·1	0·025	0·0028
14	19·26	2·14	50	5	18·7	46·5	0·241	0·318	0·077	0·0125	0·2502	0·2077	0·4	224	4315	17·2	0·033	0·0037
60	29·88	3·32	78	10	18·8	45·3	0·194	0·299	0·105	0·0626	0·3616	0·2990	0·4	151	4508	15·8	0·047	0·0053
18	31·18	3·46	81	12	18·7	47·4	0·104	0·267	0·163	0·0412	0·3625	0·3213	0·5	148	4602	24·1	0·075	0·0084
62	34·17	3·80	89	14	19·5	46·1	0·097	0·253	0·156	0·0537	0·3922	0·3385	0·5	134	4568	20·7	0·071	0·0079
13	35·7	3·97	93	14	20·1	46·5	0·238	0·517	0·279	0·0482	0·4014	0·3532	0·8	132	4702	36·7	0·131	0·0146
17	38·08	4·23	99	15	18·3	47·5	0·156	0·305	0·149	0·0430	0·2414	0·1984	0·8	240	9131*b*	35·7	0·136	0·0151
15	39·37	4·37	104	16	19·1	46·6	0·262	0·746	0·484	0·0480	0·4215	0·3735	1·3	125	4920	60·5	0·238	0·0264
12	39·90	4·43	104	16	19·0	46·5	0·131	0·279	0·148	0·038	0·242	0·206	0·7	228	9097*a*	33·7	0·134	0·0149
63	40·34	4·48	105	18	9·6	46·5	0·077	0·421	0·344	0·065	0·412	0·347	1·0	133	5357	45·7	0·184	0·0204
10	40·6	4·51	106	16	5·0	46·3	0·126*	0·326	0·200	0·0495	0·2750	0·2255	0·9	206	8364*a*	41·2	0·167	0·0186
16	43·79	4·87	114	20	12·1	47·0	0·201	1·182	0·981	0·0473	0·4400	0·3927	2·5	117	5114	114·6	0·50	0·056
65	43·93	4·88	115	21	7·6	46·2	0·060	1·257	1·197	0·061	0·428	0·367	3·3	122	5368	146·3	0·64	0·071
61	49·21	5·47	129	25	6·5	45·4	0·188	2·208	2·020	0·076	0·514	0·438	4·6	99	4871	200·0	0·98	0·109
GROUP 2.			GAS FIRE "A."		Air/Gas Ratio, 1·90.							Normal Gas Rate, 38·3 C.Ft. per Hour.						
67	29·69	3·30	78	16	19·5	44·3	0·073	0·164	0·091	0·0448	0·3412	0·2964	0·3	149	4427	13·6	0·040	0·0045
69	33·93	3·77	89	22	19·6	46·5	0·079	0·187	0·108	0·0509	0·4042	0·3533	0·3	130	4421	14·1	0·048	0·0053
70	40·92	4·55	107	30	9·4	46·2	0·083	0·233	0·150	0·061	0·435	0·374	0·4	123	5033	18·4	0·075	0·0084
68	47·16	5·24	123	38	6·6	44·1	0·092	0·535	0·443	0·064	0·484	0·420	1·1	104	4909	46·1	0·218	0·0242
GROUP 3.			GAS FIRE "B."		Air/Gas Ratio, 1·38.							Normal Gas Rate, 42·6 C.Ft. per Hour.						
21	21·26	2·13	50	6	10·0	48·2	0·171	0·244	0·073	0·0659	0·2954	0·2295	0·3	209	4448	15·3	0·033	0·0033
23	30·20	3·02	71	13	18·3	49·0	0·151	0·334	0·183	0·0595	0·3639	0·3044	0·6	160	4832	29·3	0·088	0·0088
26	32·48	3·25	76	15	14·5	50·0	0·095	0·551	0·456	0·0403	0·3398	0·2995	1·5	165	5346	75·1	0·244	0·0244
27	34·68	3·47	81	16	5·1	50·0	0·281	1·222	0·941	0·068	0·425	0·357	2·6	137	4737	128·6	0·45	0·045
22	39·00	3·90	92	20	4·8	49·0	0·183	1·878	1·695	0·075	0·435	0·360	4·7	130	5066	220·2	0·86	0·086
28	45·61	4·56	107	27	2·9	50·0	0·170*	1·907	1·737	0·055*	0·418	0·363	4·8	132	6016	229·1	1·04	0·104
24	50·58	5·06	119	30	1·9	49·0	0·170*	2·168	1·998	0·055*	0·450	0·395	5·1	111	5625	222·2	1·12	0·112
25	50·58	5·06	119	30	1·9	49·0	0·170*	2·240	2·070	0·055*	0·460	0·405	5·1	108	5478	224·2	1·13	0·113
29	50·65	5·06	119	33	2·9	50·6	0·170*	1·778	1·608	0·055*	0·432	0·377	4·3	128	6462	205·2	1·04	0·104
GROUP 4.			GAS FIRE "B."		Air/Gas Ratio, 1·87.							Normal Gas Rate, 42·6 C.Ft. per Hour.						
36	20·70	2·07	49	6	19·8	46·4	0·073	0·134	0·061	0·045	0·247	0·202	0·3	228	4729	13·9	0·029	0·0029
30	30·14	3·01	71	13	18·9	46·3	0·143	0·196	0·053	0·0515	0·3440	0·2925	0·2	158	4762	8·4	0·025	0·0025
39	30·53	3·05	72	13	19·0	46·0	0·124	0·187	0·063	0·0487	0·3372	0·2885	0·2	157	4787	9·9	0·030	0·0030
35	30·73	3·07	72	13	10·2	47·8	0·215	0·328	0·113	0·0686	0·3597	0·2911	0·4	164	5027	18·5	0·057	0·0057
33	34·90	3·49	82	16	17·6	47·5	0·164	0·329	0·165	0·0515	0·3962	0·3447	0·5	137	4785	22·6	0·079	0·0079
34	40·43	4·04	95	21	8·6	47·8	0·162	0·607	0·445	0·0543	0·4363	0·3820	1·2	124	5010	55·0	0·222	0·0222
31	45·88	4·59	108	28	2·9	46·3	0·170*	1·229	1·059	0·055*	0·485	0·435	2·4	105	4817	111·2	0·51	0·051
37	46·47	4·65	109	28	2·9	47·1	0·170*	0·914	0·744	0·055*	0·442	0·387	1·9	120	5553	88·9	0·41	0·041
32	51·19	5·12	120	34	2·9	46·3	0·170*	1·152	0·982	0·055*	0·494	0·439	2·2	103	5277	101·2	0·52	0·052
38	52·02	5·20	122	34	2·9	47·1	0·170*	0·865	0·695	0·055*	0·518	0·463	1·5	100	5226	69·6	0·36	0·036

* Assumed value. *a* Sampled from gas fire flue extension without damper. *b* No damper in chimney.

TABLE I. (*continued*).—*Special Experiments.*

Test No.	Gas Rate. C.Ft. per Hour. Total.	Gas Rate. C.Ft. per Hour. Per Radiant.	P.Ct. Normal Rate.	Pressure, Tenths In. w.g.	Approximate Volumes of Samples. Litres.	CO_2 from Gas. P.Ct.	Carbon Monoxide, Parts per 10,000. As Sampled. Air.	Carbon Monoxide, Parts per 10,000. As Sampled. Products.	Carbon Monoxide, Parts per 10,000. Difference. (9)—(8)	Carbon Dioxide, P.Ct. As Sampled. Air.	Carbon Dioxide, P.Ct. As Sampled. Products.	Carbon Dioxide, P.Ct. Difference. (12)—(11)	Ratio. $\frac{CO}{CO_2}$ P.Ct. $= \frac{(10)}{(13)}$	Dilution Factor.	Ventilation up Flue. C.Ft. per Hour.	Carbon Monoxide Produced. Parts per 10,000 of Gas Burned.	Carbon Monoxide Produced. C.Ft. per Hour.	Carbon Monoxide Produced. C.Ft. per Radiant per Hour.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
GROUP 5.			GAS FIRE "A" WITH TYPE "B" RADIANTS.					Air/Gas Ratio, 1·48.					Normal Gas Rate, 38·3 C.Ft. per Hour.					
57	27·29	3·03	71	9	17·9	45·2	0·088	0·141	0·053	0·0508	0·3085	0·2577	0·2	175	4775	9·3	0·027	0·0030
56	35·55	3·95	93	14	8·0	45·5	0·090	0·163	0·073	0·047	0·335	0·288	0·3	157	5592	11·5	0·041	0·0046
58	41·66	4·63	109	19	9·4	45·8	0·076	0·183	0·107	0·054	0·405	0·351	0·3	130	5420	13·9	0·058	0·0064
GROUP 6.			GAS FIRE "B" WITH TYPE "A" RADIANTS.					Air/Gas Ratio, 1·87.					Normal Gas Rate, 42·6 C.Ft. per Hour.					
55	29·46	2·95	69	12	12·2	45·1	0·091	0·295	0·204	0·0405	0·2946	0·2541	0·8	176	5190	35·9	0·106	0·0106
51	30·02	3·00	70	13	19·2	45·0	0·126	0·283	0·157	0·0449	0·3213	0·2764	0·6	162*	4863	25·4	0·076	0·0076
48	34·32	3·43	80	16	18·9	45·5*	0·072	0·964	0·892	0·0409	0·3113	0·2704	3·3	163	5591	145·3	0·499	0·0499
53	35·01	3·50	82	17	20·2	45·1	0·066	0·759	0·693	0·0392	0·3519	0·3127	2·2	141	4936	97·7	0·342	0·0342
20	39·47	3·95	93	21	17·9	45·9	0·174	2·109	1·935	0·0374	0·3913	0·3539	5·5	122	4835	237	0·94	0·094
52	39·75	3·98	93	21	7·4	44·4	0·117	1·690	1·573	0·060	0·409	0·349	4·5	122	4837	191	0·76	0·076
49	44·18	4·42	104	26	3·6	45·6	0·110*	3·497	3·387	0·050*	0·361	0·311	10·9	132	5840	448	1·98	0·198
50	49·00	4·90	115	31	3·6	45·6	0·110*	4·829	4·719	0·050*	0·391	0·341	13·8	118	5757	554	2·72	0·272
54	55·46	5·55	130	40	5·3	44·9	0·098	5·412	5·314	0·052	0·465	0·413	12·9	96	5341	512	2·84	0·284
GROUP 7.			GAS FIRE "B" WITH TYPE "B" RADIANTS AND "CROSS-PIECES."															
45	35·71	3·57	84	17	20·3	45·5	0·110	0·371	0·261	0·0473	0·3845	0·3372	0·8	134	4778	34·9	0·124	0·0124
46	42·52	4·25	100	23	6·6	44·7	0·107	2·294	2·187	0·058	0·396	0·338	6·5	124	5285	272	1·16	0·116
19	40·40	4·04	95	22	16·9	47·1	0·179	2·070	1·891	0·0433	0·2407	0·1974	9·6	218	8802	412	1·66	0·166
9	21·43	2·14	50	7	6·0	48·8	0·161	0·400	0·239	0·043	0·531	0·488	0·5	99	2132	23·8	0·051	0·0051
8	21·45	2·14	50	7	3·7	48·2	0·123	0·728	0·605	0·0468	0·4280	0·3812	1·6	124	2668	75·3	0·162	0·0162
4					3·4	47·0*	0·16*	10·16	10·00	0·045*	0·832	0·787	12·7	53	2280	530	2·28	0·228
5					3·6	47·0*	0·16*	9·97	9·81	0·045*	0·804	0·759	12·9	55	2360	538	2·31	0·231
3	43	4·3*	101	25	3·2	47·7	0·124	10·40	10·28	0·077*	0·844	0·737	13·4	55	2360	563	2·42	0·242
7	approx.	approx.		approx.	3·1	46·3	0·16*	11·94	11·78	0·045*	0·859	0·814	14·5	50	2150	586	2·52	0·252
6					3·0	46·3	0·16*	12·16	12·00	0·045*	0·853	0·808	14·9	50	2160	599	2·58	0·258
GROUP 8.			GAS FIRE "B." MISCELLANEOUS EXPERIMENTS.															
44	35·92	3·59	84	18	19·7	45·0	0·100	0·642	0·542	0·0412	0·2190	0·1778	3·1	246	8828*b*	133·3	0·48	0·048
43	44·30	4·43	104	25	6·5	44·9	0·167	1·050	0·883	0·047	0·256	0·209	4·2	206	9126*b*	181·9	0·81	0·081
40	44·63	4·46	105	25	4·1	44·2	0·135	4·364	4·229	0·048	0·444	0·396	10·7	101	4508	427	1·91	0·191
41	36·15	3·62	85	17	18·5	44·7	0·188	1·570	1·382	0·0530	0·4080	0·3550	3·9	121	4378	167·4	0·61	0·061
42	44·57	4·46	105	25	6·4	44·6	0·074	1·185	1·111	0·047	0·311	0·264	4·2	162	7220*b*	180·0	0·80	0·080
GROUP 9.			GAS FIRES WITH RADIANTS REMOVED.															
66*c*	29·09	3·23	76	9	18·6	46·5	0·080	0·162	0·082	0·0467	0·3467	0·3000	0·3	155	4494	12·7	0·037	0·0041
59*c*	30·84	3·43	80	10	19·4	45·8	0·103	0·178	0·075	0·0526	0·3258	0·2732	0·3	167	5156	12·5	0·039	0·0043
47*d*	35·45	3·54	83	16	19·3	45·4	0·092	0·167	0·075	0·0647	0·3493	0·2846	0·3	159	5632	11·9	0·042	0·0042

*Assumed values. *b* No damper in chimney. *c* Gas Fire "A." *d* Gas Fire "B."

primary air-gas ratio determined for the normal gas rate and after the radiants and burner had attained a steady thermal condition was 1·48, corresponding with 38·2 p.ct. of the theoretical air requirement for the gas used.

With half the specified gas rate (Tests 11, 64, and 14) barely half the fire was heated, and that not very effectively; but with 80 p.ct. of the normal rate the fire was nicely heated to the radiant clip (Tests 60, 18). The normal gas rate heated the radiants to the top without any escape of flame above them. Between 110 and 115 p.ct. of the normal gas rate the heating of the radiants became more intense, but trifling and uncontrollable changes in the condition of the fire or gas supply seemed to determine whether small flames would be projected through the tops of the radiants or not. (Tests 15, 12, 63, 10, 16 65.) With a greater excess of gas than 15 p.ct., flames were permanently projected through the tops of the radiants and licked up the firebrick back for some inches; this condition was realized with a pressure of 2 to 2·5 in. w.g.

It will be observed that in all the tests with this fire the CO_2 in the chimney gases was less than 0·5 p.ct., and that with the exception of the tests at high gas rates (Tests 16, 65, 61), the corrected value for the CO in the chimney gases has been well below 0·5 part per 10,000. The proportion of CO in the flue gases lies between 0·4 and 1·0 p.ct. of the amount of CO_2 (except Tests 16, 65, 61).

The ventilation shows a systematic increase as the gas rate increases, but the ventilation is not proportional to the gas rate; there are also irregular fluctuations of ± 10 p.ct. in the ventilation, due to variation in weather conditions. For convenience in testing, the ventilation was restricted by a damper, and ranges in the different experiments between 4100 and 5400 c.ft. per hour. The dilution factor is subject to irregular fluctuations in the same way as the ventilation, but fig. 6 shows that there is also a systematic change in the dilution factor with gas rate.

The production of CO per unit of gas burned increases in a regular manner as the gas rate increases, and three well-marked stages can be distinguished. In the first stage the CO production shows only a small change. At half the normal gas rate the CO production was about 15 parts per 10,000 of gas supplied to the fire, and this value increased very gradually to 30 parts of CO per 10,000 of gas burned, when the normal gas rate was reached, corresponding with the proper filling of the radiants with flame. (CO = 0·3 p.ct. of gas used.) In the second stage the CO production increases very considerably for a small increase in gas rate, and with a 15 p.ct. overload on the fire a value of 150 parts of CO per 10,000 of gas burned was reached. The third stage corresponds with the projection of flame through the radiants, and although there is a further increase in the rate of CO production, it is not so rapid as in the second stage. We have, in fact, obtained a *reduction* in CO output by increasing the gas rate beyond a certain point with the other fire, which shows the three stages in a more pronounced manner than the fire under discussion. The highest figure recorded for this fire when worked with a 30 p.ct. overload was 200 parts of CO per 10,000 of gas burned—*i.e.*, 2 p.ct. of the gas supplied to the fire.

The total volume of CO produced per hour with the fire burning at the normal rate was only about 0·12 c.ft. Nevertheless it is not desirable that this quantity should be discharged into the air of the room, and there is still good reason for continuing the practice of ensuring that all such appliances communicate with efficient flues.

The influence of the type of radiant upon CO production is discussed in Section IV. It will be observed that at the normal gas rate the thermal loss due to CO in the flue gases is only 0·2 p.ct. of the calorific value of the gas.

Results of Tests. Gas Fire "A," Group 2. (Increased Aeration.)

When gas fire "B" was tested it was found that an increase in the degree of primary aeration had a marked effect in reducing the production of carbon monoxide. Small as are the values obtained with gas fire "A," we repeated some of the tests with the highest degree of aeration we could conveniently attain. Using the same grade of gas as before, and readjusting the nipple, we were able to reach an air-gas ratio of 1·90 at the normal gas rate and with a pressure of 2·7 in. w.g. at the nipple.

In some respects the fire was not so satisfactory as before. At the normal rate the flames were 4¾ in. long (without radiants), but were more slender than with the former adjustment, while the inner cones were smooth in outline, very conspicuous, and only one-third of the length of the flames. There was only a slight hiss from the fire, which could be lighted or extinguished without any trouble due to back-firing. At half the normal gas rate much less than half the length of the radiants was satisfactorily heated, although the fireclay pips on the backs of the radiants became intensely hot, giving the fire a peculiar spotted appearance. At the normal rate this effect was still visible, but as the radiants became hot this local overheating was not so noticeable. When the gas rate was further increased the whole fire became intensely hot, and was taking with effect considerably more than its rated consumption of heat units. Flames were not forced through the tops of the radiants even at the highest gas rate used, 23 p.ct. in excess of the normal rate.

The results of these tests are given in Table I., Group 2, and fig. 6. The noteworthy features of this series of tests with increased aeration are the reduction in the amount of CO produced at corresponding gas rates and the extension of the working range over which the CO production is small. Thus, at three-quarters of the normal gas rate, the production of CO was only 13 parts per 10,000 of gas burned, rising to 16 parts per 10,000 at the normal rate, or roughly half the amount with the former aeration adjustment. The highest CO production observed was less than 50 parts per 10,000 of gas burned with a 25 p.ct. overload on the fire.

The adjustment of a gas fire will in general be made with a view to fitting the flames to the radiants and securing the highest radiant and thermal efficiencies, and it does not follow that these conditions will necessarily be those of minimum CO production. Although we have not been able to accompany our CO determinations with measurements of radiant efficiency, we believe that for this fire the adjustment used in our first series of tests represents better all-round working conditions, despite the somewhat greater CO production, than the higher aeration adjustment of the second series. The thermal loss was in either case small, and such CO as was formed was effectively removed by the chimney.

SECTION III.

GAS FIRE "B" (Pre-War Model).

Installation and Adjustment.

An examination was made of the products of combustion from the 10-radiant fire shown in fig. 4; and besides determining the amount of CO produced by the fire under ordinary conditions of use, we made an extended study of this fire, because the production of CO could be varied over a wide range by simple alterations in the operating conditions.

The fire was a popular pre-war model (date 1911) and many are still in use. It has already been described, for the aeration tests of our Eleventh Report (pp. 91-98) were made upon this fire, and since that time it has been in regular use for heating the testing room. The fire is fitted with a 3-orifice injector, and air regulation is by a sliding collar. The burner teats are drilled in the body of the burner and are $\frac{5}{32}$ in. dia. The fire was fitted with 8½ in. radiants of type "B," fig. 5a, and appeared to be in good working order. According to current practice the flue opening would be considered rather small for a fire of this size, being a rectangular opening 9½ by 1¼ in. (12 sq. in.), and there was no auxiliary air-inlet provided. Owing to the construction of the fireplace, however, the gas fire could not be placed against it to form a good joint, and a small gap communicating with the chimney was left between the fireplace and the gas-fire casting which would be equivalent to an auxiliary air-opening of 20 sq. in. Thus the total outlet area available for ventilation and discharge of products of combustion was 32 sq. in., and does not therefore differ greatly from that provided for gas fire "A" (36 sq. in.).

The general conditions of gas supply and method of testing are identical with those already given for gas fire "A," although, on account of the larger amounts of CO produced, it has frequently been possible to obtain data

of sufficient accuracy by the use of smaller samples of the products of combustion (2 to 5 litres).

Adjustment of Fire.—Tests upon a gas fire using this type of radiant were given in the Third Report of the Gas Investigation Committee, 1920, and it was found that with a varied selection of gases the maximum radiant efficiency was attained at about the same rate of heat supply—viz., 1900 B.Th.U. (gross) per radiant per hour. The gas consumption could be increased to 2000 B.Th.U. per hour with an almost negligible drop in the radiant efficiency, and it therefore seemed reasonable to regard this fire as having the same normal consumption as that recommended for gas fire "A"—viz., 2000 B.Th.U. per radiant per hour—and the nipple adjustment was such that this rate was obtainable at a pressure of 2·4 in. w.g. With gas of 470 B.Th.U. per c.ft. and 10 radiants, the normal consumption of the fire was, therefore, taken as 42·6 c.ft. per hour.

Probably on account of the internal shape of the mixing tube and burner casting, the flames on the burner were not all alike; and in use this fire does not heat so uniformly from side to side as gas fire "A," the greatest irregularities occurring with the left hand pair of teats.

It was decided to test the fire with two degrees of aeration, representing the highest and lowest that could be regarded as reasonable adjustments for the grade of gas in use.

RESULTS OF TESTS. GAS FIRE "B," GROUP 3. (LOW AERATION.)

For these tests the air-slide was closed to leave a slot $\frac{3}{32}$ in. wide, and the fire was silent at all rates, the inner cones of the flames being just perceptible on close inspection, but without any suspicion of luminous tips. The flames were very "soft," and the setting was, in fact, that which had been used during the coal strike, and no readjustment was made when normal gas quality was restored. The primary air-gas ratio at the normal gas rate, when the fire and casting had reached a steady thermal condition, was 1·38, equivalent to 35·6 p.ct. of the theoretical air requirement of the gas. The aeration is only slightly lower than in the first set of tests with gas fire "A" (38 p.ct. theoretical aeration).

With three-quarters of the normal gas supply the radiants were heated nearly to the radiant clip and there was no escape of flame either above or behind the radiants (Test 26). With 80 p.ct. of the normal gas rate (Test 27) small flames appeared between the backs of the radiants and the firebrick backing, although the radiants were not satisfactorily heated beyond the radiant clip. When 92 p.ct. of the normal gas supply was attained, flames were visible over the whole width of the top of the fire (Test 22). The gas rate was raised to 107 and 119 p.ct. of its normal value, and we were successful in heating the radiants to the top, but with a copious show of blue flame along the tops of the radiants, which is generally regarded as an indication of waste with a gas fire. It will be observed that the presence of flame above the radiants is shown at a much earlier stage with this adjustment of the fire than with gas fire "A."

The results of the tests are given in Table I, Group 3, and fig. 7. Pressures up to 3·3 in. w.g. have been used, but the normal consumption of 42·6 c.ft. per hour was delivered with 2·4 in. w.g. at the nipple. As with the last group of tests the CO_2 in the chimney gases has been less than 0·5 p.ct. throughout, but the CO in the samples has ranged between 1 and 2 parts per 10,000 (except Tests 21, 23, 26). The ventilation of the room during the various tests ranged from 4500 to 6500 c.ft. per hour, and was, therefore, of the same order as for the tests with gas fire "A." The CO in the flue gases, expressed as a percentage of the CO_2 in them, varied from 0·3 to 5·1 p.ct.

The production of CO per unit of gas burned covered about the same range as with gas-fire "A," and showed the same three stages, but the distribution of the three stages was somewhat different. The CO production at half rate was 16 parts per 10,000 of gas burned, as with gas fire "A," but the end of the stage of gradual increase of CO (reached at about the normal gas rate with gas fire "A") may be taken as 3·0 c.ft. per radiant per hour, corresponding with only 70 p.ct. of the normal gas rate and a CO production of 33 parts per 10,000 of gas burned. The radiants are smaller, and with this air-adjustment become filled with flame at an earlier stage.

The second stage, in which the CO production rises rapidly, was finished before the normal gas rate was attained, and 90 p.ct. of the normal gas rate with a CO production of 200 parts per 10,000 of gas burned may be taken as marking the end of this stage. At the normal gas rate of 2000 B.Th.U. per radiant per hour the CO production was 235 parts per 10,000 of gas burned—the maximum value observed for this adjustment of the fire.

In the third stage flames were projected through the radiants, but there was no further increase in the CO production per unit of gas burned, even when the normal gas rate was exceeded by 20 p.ct. On the contrary, a slight but definite reduction in the CO in the flue gases was observed when flames were established above the radiants.

Although with this adjustment of the fire the *maximum* CO production was not sensibly different from that with gas fire "A," the CO production at the normal rate was about 8 times as great; and while an improvement could be effected by regarding a slightly lower rate as the normal rate for this fire, the CO production would still be relatively high. The production of CO at the normal rate was 0·98 c.ft. per hour, as against 0·12 c.ft. for gas fire "A." There is no question that this fire must be properly connected to a flue when in use.

RESULTS OF TESTS. GAS FIRE "B," GROUP 4. (HIGH AERATION.)

A second series of tests was made with gas fire "B" in which the aeration was increased to its utmost practical limit. The only stipulations were that it should be possible to work the fire at all rates up to the normal rate, and that it should be possible to light and extinguish the fire without trouble due to back-firing. The adjustment was made by drawing back the air-slide to leave a slot a full $\frac{5}{32}$ in. wide, and a primary air-gas ratio of 1·87 was attained (48·6 p.ct. of the theoretical air requirement) at the normal gas rate when the fire and burner casting had reached a steady thermal condition. The gas nipple was unaltered, and the normal gas rate of 42·6 c.ft. per hour (of 470 B.Th.U. gas) could be maintained with a pressure of 2·4 in. w.g. at the nipple.

Except at rates below half the normal gas rate the fire was objectionably noisy, and there was the added difficulty that the two left-hand flames showed a roughness, almost like excessive aeration, well in advance of the remainder of the fire. The inner cones ($\frac{3}{4}$ in. long) were smooth and well-marked at half the normal rate of gas supply, gradually lengthening to $1\frac{1}{2}$ in. and assuming a roughened outline as the gas rate was increased to 20 p.ct. above the normal rate.

At half the normal gas rate the radiants were heated for one-third of their height, while with three-quarters of the normal rate a bare two-thirds was satisfactorily heated, and there was no escape of flame either through or behind the tops of the radiants—*i.e.*, the conditions were not sensibly different from those with the lower degree of aeration, although the radiants seemed a little hotter. By the time that 95 p.ct. of the normal rate was reached (at which there was a marked escape of flame in the former tests) only a slight escape of flame above the radiants was visible, and there was no serious escape of flame above the radiants until a 20 p.ct. overload had been reached (Tests 32 and 38). At this rate thin blue flames about $2\frac{1}{2}$ in. long were licking up the firebrick back.

The results are indicated in Table I, Group 4, and by fig. 7. The CO_2 in the chimney gases as sampled was below 0·5 p.ct., and except at high gas rates (Tests 31, 37, 32, and 38) the CO in the flue gases was much less than 1 part per 10,000. The ventilation of the room in this group of tests was between 4700 and 5500 c.ft. per hour.

In its general character the CO production curve is similar to those already described. There was a gradual increase in CO production per unit of gas burned as the gas rate was increased, but the transition between the first and second stages we have described was not so marked. Starting with only 7 parts of CO per 10,000 of gas burned at half the normal rate, the CO production gradually increased to 80 parts per 10,000 at the normal rate. This is clearly a very great improvement on the

conditions represented by the lower aeration adjustment (235 parts per 10,000). On overload with the higher degree of aeration the maximum CO production was 100 parts per 10,000 of gas burned, as against 200 parts per 10,000 for gas fire "A" with normal aeration. The production of CO by the fire was 0·34 c.ft. per hour at the normal gas rate.

One peculiar feature with this fire is a reduction in the proportion of CO per 10,000 of gas burned when the fire is forced so that stable flames are formed above the radiants. Tests 31 and 32 were made in succession under almost identical conditions except as to gas rate; and the results are confirmed by another special pair, Nos. 37 and 38, although the points for 37 and 38 lie below those for 31 and 32 respectively. (At the lower degree of aeration tests 28 and 29 exhibit the same phenomenon.) Contrary to popular opinion, therefore, it would appear that the maximum production of CO occurs just before and not after flames make their appearance above the radiants.

In practice, it is probable that the aeration of the fire would be adjusted to a state intermediate between those used for our low and high aeration tests respectively, possibly somewhat nearer to the low aeration condition in order to reduce the noise from the fire. The figures for CO production would probably lie in the space bounded by the curves in fig. 7, and about 150 parts of CO per 10,000 of gas burned might be expected from this fire as usually adjusted, and when working at a rate of 2000 B.Th.U. per radiant per hour.

SECTION IV.

INVESTIGATION OF FACTORS INFLUENCING CO FORMATION.

If the results obtained with the two gas fires are compared, it will be seen that there are decided differences between them; and it was considered desirable to investigate this matter and ascertain what features of construction or operation would account for the improved results obtained with gas fire "A." For this purpose the results already available were supplemented by a series of experiments made under suitably chosen conditions, although some departure from normal conditions of use was necessarily involved.

As the radiants were of different patterns, it was thought that useful information would be obtained by interchanging the radiants of the two fires. The results are indicated in Table I, Group 5, for gas fire "A" when fitted with the older Type "B" radiants, and in Table I, Group 6, for gas fire "B" and Type "A" radiants. (See also fig. 8, Curves 5 and 6 respectively.) There are now six sets of figures available, represented by the six curves in fig. 8, from which several deductions can be made as is indicated below.

Effect of Changing Degree of Primary Aeration.

For either fire, used with its own radiants, there was a marked diminution in the production of CO at corresponding gas rates when the primary aeration was increased. This is evident if comparison is made either of Curves 1 and 2 for gas fire "B," or Curves 3 and 4 for gas fire "A," although the change in air-gas ratio was not large in either case (from 1·48 to 1·90 for gas fire "A"; from 1·38 to 1·87 for gas fire "B"). At the normal gas rate the production of CO fell from 30 parts per 10,000 of gas burned down to 16 parts per 10,000 for gas fire "A," and from 235 parts per 10,000 of gas burned down to 80 parts per 10,000 for gas fire "B." We have, however, noted elsewhere that the higher degree of aeration does not necessarily represent a better working condition for the fires.

Comparison of Two Types of Radiants.

Type "B" Radiants.—These were the radiants supplied with gas fire "B," and are shown on the left of fig. 5a. They consist of straight fireclay tubes 8¼ in. long, perforated with diagonal slots at the back (arranged in a "herring-bone" fashion) and covered internally with pips or studs of fireclay. There is little room for the escape of products of combustion through the top. Observation showed that, while the flames burned up the centre of the fireclay tube, a considerable amount of flame passed through the slots and burned in the spaces between the radiants and the face of the firebrick back, assisting to some extent in maintaining the temperature of the radiating surface.

The appearance of the space between the top of the radiants and the firebrick back is not good, and originally special top pieces were provided to fill in the gap. To avoid stocking these special pieces, damaged or shortened radiants were frequently placed horizontally across the tops of the radiants; and as the special blocks were not available, we adopted this practice for those experiments in which "cross-pieces" were used. In all other experiments only the vertical pieces were used. The cross-pieces or top blocks act as dampers on the space between the radiants and the firebrick slab, and most of the flame is compelled to traverse the tube of the radiant, a smaller proportion going through to the back. It is plain, however, that any unburned or partly burned gases going through to the back will be very unfavourably placed for securing the necessary secondary air for completing the

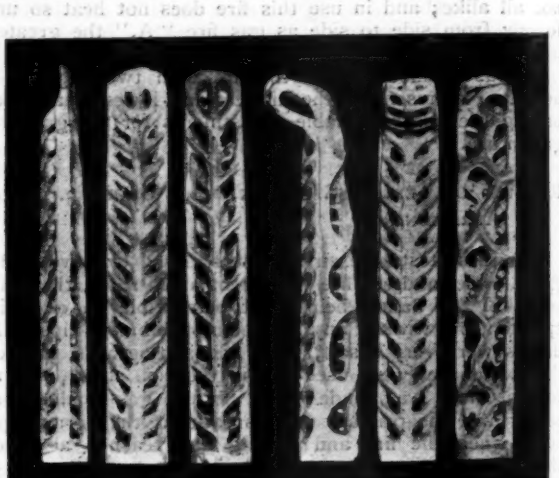

FIG. 5a.—SIDE, REAR AND FRONT VIEWS OF RADIANTS.
Type "A" on right; Type "B" on left.

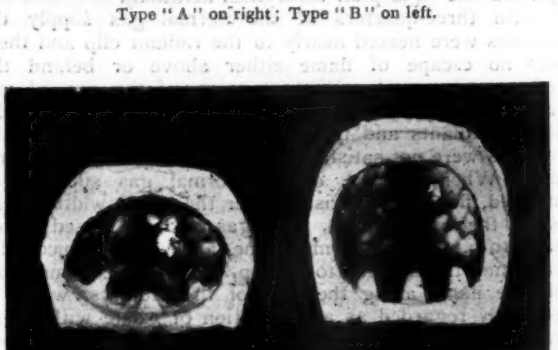

FIG. 5b.—END VIEW OF RADIANTS (APPROXIMATELY FULL SIZE).

combustion, and the results we have obtained support this view.

Type "A" Radiants.—These were supplied with gas fire "A," and represent a later development of the Type "B" variety. They are shown on the right of fig. 5a. The need for separate top blocks is avoided by bending the radiant over near the top. The back is perforated as before and the bent portion acts as the damper. A small fireclay projection on each radiant prevents close contact with the firebrick slab at the back. The two radiants are of equal width, but there is a striking difference in depth from back to front. The Type "A" radiants are 1¼ in. from back to front near the base, as against 1 in. for the older Type "B" radiants. This is clearly shown in the end views of the radiants, fig. 5b.

The results obtained when the older Type "B" radiants were fitted to gas fire "A" were very remarkable, showing the lowest CO production observed in any of our tests. Starting with 9 parts of CO per 10,000 of gas burned at three-quarters of the normal gas rate, the

CO production rose uniformly, but only slightly, to 14 parts per 10,000 of gas burned with a 10 p.ct. overload on the fire. The normal aeration setting was used as for the tests of Group 1, but the CO production curve lies wholly below that for the tests of Group 2, where a higher degree of primary aeration was used—*i.e.*, the change in the type of radiant caused a greater alteration in CO production than the change in aeration.

These results refute the suggestion that higher CO figures were obtained with gas fire "B" because its radiants are of smaller bore and may cramp the flames or hinder secondary aeration. For Tests 56 and 58, the radiants were fully heated, and the space behind them was at a bright red heat even near the top—a condition which is apparently favourable for completing combustion with secondary air drawn through the upper parts of the radiants.

The experiments with Type "A" radiants fitted to gas fire "B" are of some practical importance, for it is possible that these radiants would be fitted to the older fires when renewal becomes necessary. The tests were made with the higher degree of primary aeration (air-gas ratio 1·87) and the fire presented a satisfactory appearance; flames were not visible above the radiants until the normal gas rate had been exceeded. There was nothing, therefore, in the behaviour of the fire which would lead one to expect a CO production curve like that shown in fig. 8, Curve 6. It is of the same general character as those previously described, but the features are much accentuated. There is nothing unusual below 70 p.ct. of the normal gas rate, but above this rate the CO production curve is exceptionally steep, rising to practically 500 parts of CO per 10,000 of gas burned (*i.e.*, 5 p.ct. of the gas) at 4·5 c.ft. per radiant per hour. At higher gas rates flames were established above the radiants, and after rising to a maximum of 555 parts of CO per 10,000 of gas burned at 5 c.ft. per radiant per hour the CO output showed a slight reduction. The high CO values are not isolated examples, but are part of a systematic arrangement in Curve 6, and receive a certain amount of support from Tests 3 to 7 (inclusive) of Group 7.

It is difficult to find a complete explanation of the observed results. They do, however, indicate that visual observation of the condition of a fire in operation is not entirely trustworthy when CO formation is in question. They also suggest that it is unwise to employ radiants in a fire which were not expressly designed for that fire. In these special experiments CO was formed in amounts that would be dangerous, but for the fact that the products of combustion were effectively removed by the flue. It is plain, however, that a stage had been reached at which the thermal loss due to CO in the flue gases could no longer be overlooked, amounting as it did to some 3 to 4 p.ct. of the thermal value of the gas

Curves 1 and 5 represent tests in which Type "A" and Type "B" radiants respectively were used in gas fire "A" under comparable conditions with the normal degree of aeration. Up to the normal gas rate the relative CO production for the two radiants is approximately in the ratio of 2 : 1, the older radiants showing the lower figure; and if the gas rate is increased the disparity is more marked. Curves 6 and 4 also represent tests in which Type "A" and Type "B" radiants respectively were used in the same fire, in this case gas fire "B," with equal degrees of aeration (air-gas ratio = 1·9). Here again the older radiants yielded lower CO values, the ratio being approximately 4 : 1 over the greater portion of the working range. In both cases, therefore, the older radiants were superior in showing a lower CO production.

We have no information respecting the relative radiant efficiencies of the two types, but this, rather than the CO production, is likely to be the factor influencing their selection in practice. Some light is thrown on the difference between the two types of radiants in the later section, "Modification of Radiants."

Comparison of Fires "A" and "B."

The foregoing results may also be used to compare the two fires when fitted with the same radiants. For example, Curves 5 and 3 refer to tests on different fires with Type "B" radiants and a moderate degree of aeration (primary air-gas ratio 1·48 and 1·37 respectively). There is a very marked difference between the two fires, and from three-quarters of the normal gas rate upwards the production of CO by the older fire "B" is from 15 to 20 times as great as that by the newer gas fire "A."

Comparison can also be made of Curves 2 and 6 for different fires tested with Type "A" radiants and a high degree of aeration. The curves for the two fires are not geometrically similar, and their relative CO production depends upon the gas rate at which comparison is made. Near the normal gas rate the older gas fire "B" has a CO production about 20 times that for gas fire "A." With either type of radiant, therefore, the older fire produces decidedly more CO per unit of gas burned than gas fire "A," even when gas quality and aeration are the same for both fires.

The newer fire has a multiple-orifice injector of a type that might be expected to yield a very uniform air-gas mixture; and this, in conjunction with the refractory grids below the burner nozzles, should lead to a very steady discharge of the combustible mixture. The flames were silent and smooth in outline, as were also their inner cones. Gas fire "B," on the other hand, was always noisy (except with very low aeration), with rough spluttering flames, rough inner cones, and a tendency for the cone-height to fluctuate rapidly—a condition which might very readily be mistaken for excessive aeration. The character of the flames in the two cases would, therefore, appear to be responsible for the differences between the two fires.

It will be observed that although the new radiants lead to a higher CO production than the older ones, the difference between the two fires is so great that the combination of gas fire "A" and Type "A" radiants gives a net result which is a considerable improvement on any CO figure obtained with the older fire.

Modification of Radiants.

From their smaller bore and greater penetration of the flames, one might have expected a greater CO production from the Type "B" than from the Type "A" radiants, but the experiments already described indicate that this is not so. When it was observed that a considerable amount of flame found its way to the back of the radiants, it was at once evident that any obstruction preventing a free flow up the back could modify combustion there to a marked degree.

Experiments 45 and 46 (Table I, Group 7) were therefore conducted with gas fire "B" and Type "B" radiants under conditions identical with those prevailing for Table I, Group 4 (air-gas ratio 1·87), except that pieces of Type "B" radiants were laid as a single horizontal row along the tops of the vertical pieces. Test 45 at 84 p.ct. of the normal gas rate is only slightly above Curve 4 (fig. 8), showing that at the lower rates the influence of the cross-pieces is not very marked; but there is an unmistakable effect in Test 46 at the normal gas rate, for the CO production is nearly three-and-a-half times as great as for the corresponding conditions without the cross-pieces.

In the remaining tests of Group 7, Table I, which were among the earliest to be made, cross-pieces were used; and this, together with a slightly lower degree of primary aeration, is doubtless responsible for some of the high CO figures attained. It would, therefore, appear that these cross-pieces or their equivalent are in some respects undesirable.

The bent-over portion of the Type "A" radiants may in part account for the high CO figures recorded in Group 6. It is also possible that these radiants are too large and do not become fully heated, so that the flames are chilled and CO appears in the flue gases. It is clear, therefore, that there is still a field for investigation in devising a radiant that will yield the maximum radiant efficiency with the minimum CO production.

Tests without Radiants.

The products of combustion from both fires were examined for CO at selected gas rates under the same conditions as before except that the radiants were removed.

Tests 59 and 66 (Table I, Group 9) were made with

gas fire "A" at rather more than three-quarters of the normal gas rate, using the same injector setting as in the earlier tests with normal aeration. As the whole gas fire structure was cooler in the absence of radiants, the degree of aeration would be rather greater than in those tests, but it was not specially determined (see Eleventh Report). The above rate was chosen so as to avoid extensive flame contact with the studs on the fire-brick back, and the flames were 4 in. long, with smooth and well-marked inner cones 1¾ to 2 in. long. It will be observed that with the cooler gas nipple the pressures required for a given gas rate are a little lower than before.

Test 47 was a similar test upon gas fire "B" at 83 p.c. of the normal gas rate, with the air-shutter setting previously used for the tests with the higher degree of aeration. The flames and cones were slightly shorter than in Tests 59 and 66, but were rough and noisy. The actual degree of aeration was not determined.

From the figures given in Table I, Group 9, it is plain that detectable amounts of CO were formed even when

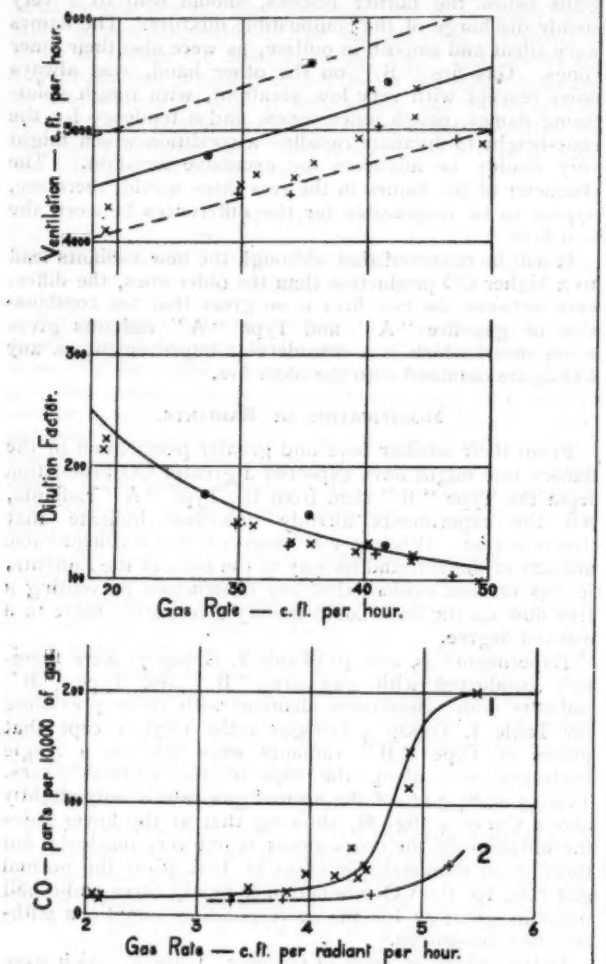
Ventilation — c.ft. per hour.
Dilution Factor.
Gas Rate — c.ft. per hour.
CO — parts per 10,000 of gas.
Gas Rate — c.ft. per radiant per hour.
1
2

FIG. 6.—TESTS WITH GAS FIRE "A."

radiants were not used, the three tests yielding an average value of 12·4 parts of CO per 10,000 of gas burned at 80 p.c. of the normal gas rate.

There is some doubt as to whether the above figure may be regarded as typical of free-burning Bunsen flames; in fact, there is reason for expecting a lower value for the latter. The determinations just mentioned were made upon a number of flames placed side by side, so that there might be mutual interference by the products of combustion, and secondary aeration could only be effected freely from the front.

SECTION V.

VENTILATION.

Most of the tests described in this report were made with the gas fires connected to a brickwork flue of 160 sq. in. cross-section and height 38 ft. For convenience in testing, the draught up the flue was restricted by a damper, and the same damper setting was invariably used.

The flow of air up the chimney prevailing in the various tests is indicated by the points on the upper sections of figs. 6 and 7 for gas fires "A" and "B" respectively. The observations covered a period of sixteen months, and show that the ventilation was subject to considerable fluctuation. For a particular installation the ventilation may be expected to change with the strength and the direction of the wind; with the difference between indoor and outdoor temperature; and with the mean chimney temperature—the latter depending partly upon heat developed by the fire in use and partly upon heat communicated from adjacent flues in the same stack.

Upon the upper part of fig. 7 two dotted lines will be found, together with a full line running through the points. The dotted lines mark out a belt representing a variation in ventilation of 10 p.c. on either side of the full line, and this belt includes practically all the observations

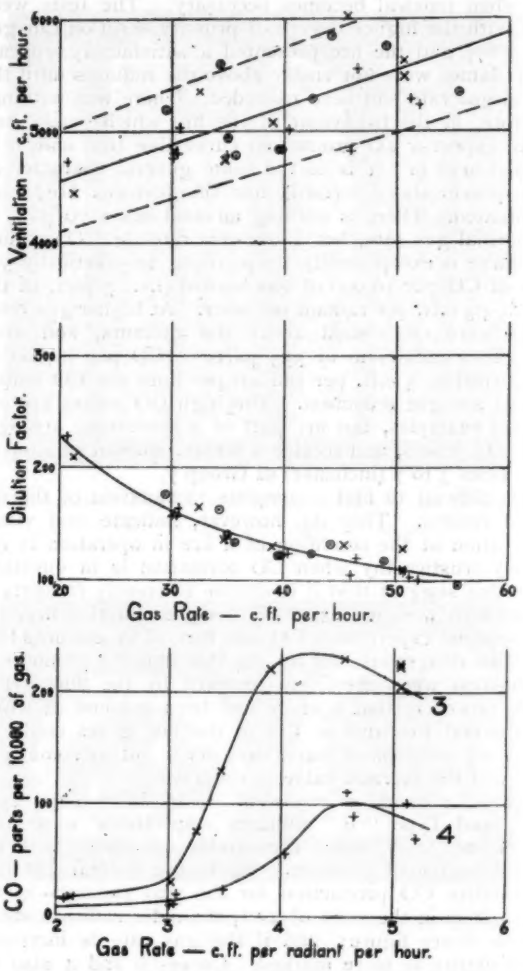
Ventilation — c.ft. per hour.
Dilution Factor.
Gas Rate — c.ft. per hour.
CO — parts per 10,000 of gas.
Gas Rate — c.ft. per radiant per hour.
3
4

FIG. 7.—TESTS WITH GAS FIRE "B."

for gas fire "B" with the damper in use. In view of the distribution of the points on fig. 7, we cannot do better than draw a straight line through them. The best-fitting straight line through the points lies a little below the full line actually drawn, but a belt 10 p.c. on either side of the best-fitting straight line would take in fewer observations than are now included.

The lines shown on fig. 7 for gas fire "B" were transferred to fig. 6. It will be observed that they fit the points for gas fire "A" tolerably well. It cannot be said, therefore, that there was any significant difference in the ventilation produced by the two fires at equal gas rates. It must be remembered, however, that the older fire had been installed in such a way that it had, in effect, an auxiliary ventilating opening into the chimney.

While there were irregular fluctuations in the ventilation effected, figs. 6 and 7 show that there was a systematic increase in ventilation as the gas rate was increased. In

these tests the ventilation rose from 4560 c.ft. per hour with a gas rate of 20 c.ft. per hour, to 5550 c.ft. per hour when the gas rate was increased to 50 c.ft. per hour. It is plain, therefore, that the ventilation was by no means proportional to the gas rate, for the increase in ventilation in these experiments was only 22 p.ct. when the gas rate was increased two-and-a-half times. If it is permissible to extrapolate the ventilation curves backwards, we find that the "natural ventilation" of the room (*i.e.*, with the gas fire extinguished) would correspond with a flow of about 4000 c.ft. per hour up the chimney.

Several experiments were made with a view to determining the amount of ventilation when the damper was withdrawn—*i.e.*, as the fires would usually be installed. Test No. 17 (Table I, Group 1) indicated a ventilation of 9131 c.ft. per hour for gas fire "A" with a gas rate of 33·1 c.ft. per hour. From Tests 43 and 44 (Table I, Group 8) a ventilation of 8920 c.ft. per hour would be deduced for gas fire "B" at the same gas rate. Within the limits of variation in ventilation, therefore, the two fires were indistinguishable, as in the tests in which the damper was used.

There was another object in making tests with the damper withdrawn—namely, to determine whether the increased draught caused any change in the CO production. The value obtained for CO production by gas fire "A" in Test 17 lies a little above the curve (fig. 6), but if comparison is made with neighbouring points, bearing in mind the high dilution factor, we cannot say that withdrawing the damper effected any significant change in CO production by this fire.

On the other hand, with gas fire "B" there was an *increase* in CO production on withdrawing the damper, which was quite outside the limits of experimental error. (Tests 43 and 44, Table I, Group 8, made with high aeration setting of air slide and to be compared, therefore, with curve (fig. 7).) This result, which was the reverse of what might have been anticipated, was at first difficult to explain. The fire is so arranged that it can be supplied with gas either from the right or from the left hand side at will, and the casting is perforated to allow the change to be made. It is thereby possible for the chimney-pull to be transmitted to the air-intake of the injector and reduce its efficiency. Experiments showed that when the damper was withdrawn the flames immediately softened with this fire, despite the many openings in the perforated fender concealing the burner. The increased CO production on withdrawing the damper is, therefore, quite consistent with the effect of a change in the degree of aeration which has already been studied.

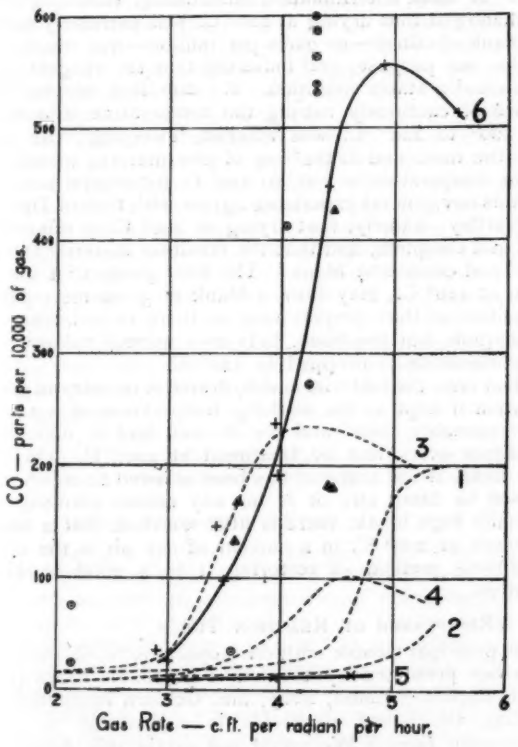

FIG. 8.—TESTS FROM SECTION VI.

With the greater pull, also, there was a tendency to distort the flames and pull them under the bottom of the radiants towards the back, a state of affairs that might well lead to an increased CO production. These effects were not observed with gas fire "A," in which the casting was carefully designed to prevent direct communication between the chimney and the injector intake. These points are of special importance in the case of gas fires which are "built-in," closely fitted to tiled fireplaces, or "sheeted-up," as is sometimes demanded by consumers.

TABLE II.—*Carbon Monoxide Production by Gas Fires "A" and "B."*

—	Gas Fire "A" (Modern).			Gas Fire "B" (Pre-War).		
Radiant.	Type "A."		"B."	Type "B."		"A."
Aeration.	Normal.	Increased.	Normal.	Low.	High.	High.
Gas Rate. C.Ft. per Radiant per Hour.	Curve 1.	Curve 2.	Curve 5.	Curve 3.	Curve 4.	Curve 6.
2	15	..	..	15	7	..
2½	15	..	..	17	8	..
2¾	16	..	..	20	9	..
2¾	16	..	..	24	11	..
3	17	..	9	33	13	30
3¼	18	13	10	75	17	58
3½	20	14	10	138	25	98
3¾	22	14	11	195	37	150
4	25	15	12	230	55	220
*4½	30	16	12	235	80	340
4¾	47	18	13	231	100	490
4¾	106	22	14	222	100	544
5	171	31	..	209	92	555
5¼	194	47	..	..	81	541
5½	200	..	..	..	..	518

* Normal gas rate.

Tests 3 to 9 (Table I, Group 7) were made with an iron flue pipe on the gas fire outlet. The flue gases were sampled close to the fire, but this scheme was abandoned as unreliable at an early stage. The ventilation figures given in Col. 16 for those tests (2100-2700 c.ft. per hour) do not represent the ventilation of the room, but the air passing up this flue extension; and the figures must not be taken as showing that a high CO production accompanies a reduced ventilation. For this particular fire, as installed in our tests, the reverse was the case. The high CO result in Test 8 was due to a violent and gusty wind producing a fluctuating pull on the chimney.

SECTION VI.

FURTHER INVESTIGATION OF IODINE PENTOXIDE METHOD FOR DETERMINATION OF CO.

After the draft of our Fifteenth Report had been prepared, a paper was published by Davies and Hartley* dealing with the iodine pentoxide method for determining traces of CO. The work was characterized by minute attention to detail; and bearing in mind the importance of the subject to a combine of gas appliance manufacturers like Radiation Ltd., it may be taken that the problem was most carefully examined.

The scope of the investigation was similar to our own, but certain aspects were treated in greater detail than in the Fifteenth Report. The information obtained is of great value; and it is pleasing to find that, although conducted quite independently, the two investigations agree so well upon essential points.

The main differences are: (1) They use a larger quantity of iodine pentoxide in a horizontal tube; (2) more elaborate absorbers are employed permitting the use of 5 p.ct. instead of 10 p.ct. potassium iodide solution; (3) slightly different procedure in finishing titrations is

* "The Determination of Traces of Carbon Monoxide," by Hamilton Davies, B.Sc., and Harold Hartley, D.Sc. (Communication from the Central Research Laboratories of Radiation Ltd.) "J.S.C.I." June 4, 1926, pp. 164-68 T.

adopted; (4) they recommend frequent treatment of the reagent at 200° C.; (5) their iodine pentoxide "blanks" were lower than ours.

It was this paper, together with one or two difficulties associated with the process we had developed, that led to further investigation, the results of which are given below to supplement the Fifteenth Report.

VIa.—Titration of Iodine Collected.

In the Fifteenth Report, it was stated that a N/10 sodium thiosulphate solution was very stable, losing strength at the rate of barely 1 p.ct. per annum. The statement was based upon observations made three months after preparing the solution. When re-standardized at the end of six months, one solution had only depreciated to the extent of 0·5 p.ct. It was intentionally kept for a further period, but the bottle was only partly full and conditions were less favourable for the preservation of the solution. By the end of twelve months the residual solution showed a deposit of sulphur, and the strength had fallen by 5 p.ct.

Nevertheless, the solution seems to be reliable for at least six months if treated with the care usually accorded to standard solutions, and we still regard dilution of a decinormal stock solution as the most convenient and satisfactory method of obtaining a freshly prepared N/500 solution of sodium thiosulphate.

In titrating the iodine collected during tests, we have reduced the final bulk of solution from 75 to 50 c.c. Fifteenth Report), and now endeavour to retain a trace of colour in the solution rather than discharge it completely (Fifteenth Report). The final stages of the titration must be conducted slowly and with great care. No special advantage has been found in adding an excess of thiosulphate and back-titrating with N/500 iodine solution as suggested by Davies and Hartley.

VIb.—Potassium Iodide "Blanks."

The action of light in liberating iodine from potassium iodide solutions has been confirmed, and may account for the progressive increase in the "blanks" for our stock potassium iodide solutions which was noted in the Fifteenth Report. We have therefore adopted the procedure of making up potassium iodide solution freshly for each test (instead of using a stock solution) and screening the absorbers from light during the test.

In a number of cases we have obtained negligible blanks, although solutions made from certain batches of potassium iodide yielded small amounts of iodine on standing, even when preserved in darkness. We have retained the use of 10 p.ct. potassium iodide solution for absorbing iodine, as this works sufficiently well in our simple absorbers up to a rate of 2 litres per hour.

VIc.—Thermal Treatment of Iodine Pentoxide.

The iodine pentoxide "blanks" given in the Fifteenth Report (equivalent to 1·7 parts of CO per million of sample at 120° C.) were sufficiently constant to permit correction for the iodine liberated during a test by spontaneous decomposition of the iodine pentoxide; but inasmuch as both the Government Chemist and Davies and Hartley were able to realize blanks of less than 1 part of CO per million, we naturally sought an explanation of the difference.

A considerable portion of the paper by Davies and Hartley (*loc. cit.*) is devoted to the thermal treatment of iodic acid, and indicates the successive stages in dehydration as the temperature is raised. It is evident from their work that at a temperature of 200° C. the dehydration is complete and relatively rapid in a stream of dry air, and that after such treatment the material, if carefully used, will show a low and consistent blank.

Our iodine pentoxide had not been subjected to a temperature of 200° C., except during its preparation several months previously, and as moreover it had stood in its stoppered tubes in the cold furnace for some ten weeks during the vacation and the preparation of our report, it seemed desirable to re-investigate the blanks. These were first of all determined under the old conditions of use—*i.e.*, the furnace was taken up to 120° C., and purified outside air was drawn through two of the tubes at a rate of 1 litre per hour for about 5 hours, after which a 16-hour blank determination was made.

This was followed by other blank determinations to confirm the results obtained, and the tests showed no higher blanks than those previously obtained when the tube was in continuous use. From the figures given in the paper by Davies and Hartley, higher blanks might have been expected after the tubes had been unused for so long, although there is no good reason why this should be so if the reaction tubes are, as in our case, securely closed and protected from moisture by phosphorus pentoxide tubes when not in use.

The material was afterwards raised to 200° C. while maintaining a current of dry air through the tubes for some hours, and traces of water were expelled from the reagent. The temperature was dropped to 120° C. and fresh blank determinations were made. The results were little different from those previously obtained, and the treatment at 200° C. was therefore repeated for a further period of 16 hours. Despite this treatment, we were unable to obtain blanks at 120° C. as low as 1 part of CO per million for the iodine pentoxide we were using.

The matter was dismissed for a time and the experiments upon the resistance of the reaction tubes, described in the next section, were undertaken. At the conclusion of those experiments we were able to report lower iodine pentoxide blanks, but the result is apparently due to the grading of the material rather than to its thermal treatment.

We have since prepared new fillings for four iodine pentoxide tubes and have made further observations on the final drying of the reagent. The iodine pentoxide used for filling was first dried in an air-oven at 180° to 200° C., leaving only 0·6 p.ct. of moisture in the material as placed in the reaction tubes; and the drying was completed *in situ* by passing a stream of dry air through the tubes and slowly raising the temperature.

In one case the temperature was raised to 120° C. only, and maintained at that value (with air-sweeping) for 24 hours. A blank determination immediately following this period showed that drying at 120° C. was extremely slow. The blank obtained—10 parts per million—was much too high for our purpose, and indicated that the reagent had not reached a stable condition. We therefore adopted the practice of cautiously raising the temperature in stages until 200° to 220° C. was reached, sweeping with dry air all the time, and in the case of new material maintaining the temperature at 200° to 220° C. for several hours.

In this our general experience agrees with that of Davies and Hartley—namely, that drying at 200° C. is relatively rapid and complete, and that the resultant material shows a low and consistent blank. The final product, if maintained at 220° C., may show a blank of 50 or more parts per million at that temperature, as there is incipient decomposition, but the blank falls to a normal value when the temperature is dropped to 120° C.

When once the material is dehydrated it remains in good condition if kept at the working temperature of 120° C. and reasonably used, and we do not find it necessary to precede every test by treatment at 200° C. On the other hand, if the material has been allowed to cool while exposed to damp air, or is for any reason showing an unusually high blank, there is little question that a short treatment at 200° C. in a current of dry air is the most expeditious method of restoring it to a good working condition.

VId.—Resistance of Reaction Tubes.

The principal trouble with our apparatus lay in the high resistance presented by the iodine pentoxide tubes (Fifteenth Report. Lamb, Bray, and Geldard recommended grinding the iodine pentoxide in a ball-mill to pass an 80-mesh sieve. We could not attain this degree of fineness, but the whole of the iodine pentoxide we used had been ground to pass a 50-mesh sieve and contained a large proportion of finer particles and dust.

From theoretical considerations it seemed likely that the resistance of the existing tubes could be reduced by employing material of a uniform size, and that larger granules might be used and still provide the surface necessary for efficient reaction.

Experimental work was carried out with a view to selecting the most useful size of material for our purpose. Crushed firebrick of different sizes was used, graded within small limits by passage through standard I.M.M. sieves.*

* The standard laboratory sieves of the Institute of Mining and Metallurgy, in which the mesh number is the number of wires per inch, and wires and spaces are of equal width.

The smallest material used was 40-50 mesh and the largest 8-10 mesh. Each grade of material in turn was placed in a vertical glass tube about 1·2 cm. dia., gently tapped down, and the length of column (about 20 cms.) measured. Air was drawn through the column by an aspirator, the suction required for different rates of flow being observed.

The results obtained may find useful application not only to iodine pentoxide but to soda-lime, calcium chloride, and other granular materials used for filling tubes in the laboratory, and possibly also in the case of experiments dealing with reactivity of coke and other materials.

The surface of material available in a given reaction tube will be proportional to the mesh number of the material filling it. On the other hand, the back-pressure was found to be proportional to the square of the mesh number, to the length of column in the tube, and to the rate of flow, measured in litres per hour per sq. cm. of cross-section of the tube.*

The size of material proposed in the Fifteenth Report seemed suitable for a trial in one of the original reaction tubes, and some iodine pentoxide was graded to pass a 20-mesh I.M.M. sieve but to rest on a 30-mesh sieve (*i.e.*, material with particles about 1/50 in. or 0·5 mm. dia.). The material was readily prepared by emptying one of the existing tubes, moistening the contents with water to give a crumbly mass, drying at 180° C. in an air-oven, crushing in a mortar, and taking that portion which passed a 20 but rested on a 30 mesh I.M.M. sieve. The portion passing the 30-mesh sieve was moistened and re-treated until, with the addition of a small reserve of iodine pentoxide, enough of the desired grade was collected to fill the reaction tube to its original level. The tube was then sealed and its contents dehydrated *in situ* at 220° C.

The resistance of the old tubes of fine material was about 4 in. water gauge per litre per hour each, but the resistance of the new tube with the 20-30 mesh filling was only 0·06 in. water gauge. The resistance was in good agreement with expectations, and so far as reduction of resistance is concerned our object had been attained.

The tube was carefully examined as to its suitability for the determination of CO, and our experience suggested that advantages would be gained by using slightly smaller granules than 20 to 30 mesh. A medium grade of iodine pentoxide (30 to 50 mesh) was therefore prepared in a similar manner and tested. The surface available for reaction had been increased by approximately 60 p.ct.; and the resistance, though increased to 0·2 in. w.g. per litre per hour, was still a great improvement on the tubes originally used. This medium grade of material (30 to 50 mesh) was found to be satisfactory, and has been used for all our gas fire tests from No. 21 onwards.

The reduced resistance of the tubes as compared with those previously used has enabled a greater rate of sampling to be achieved when required, 3 litres per hour now being possible instead of 1 litre. Care must be exercised, however, to see that this rate is not in excess of that which can be satisfactorily dealt with by the iodine pentoxide and by the iodine absorbers (see Section VIF).

VIE.—IODINE PENTOXIDE "BLANKS" AT 120° C.

It has been pointed out (Section VIc) that the iodine pentoxide blanks given in the Fifteenth Report were consistent, and definite corrections could therefore be applied for them, but it was desirable that the blanks should if possible be brought below 1 part of CO per million of sample. It seemed reasonable to assume that unless the blanks were analogous to a vapour pressure or an equilibrium concentration, the amount of iodine liberated by spontaneous decomposition would be proportional to the mass of iodine pentoxide in the reaction tube.

We therefore constructed a smaller tube, containing only 8 grammes of iodine pentoxide (20 to 30 mesh), the diameter of the tube being 1 cm. and the length of iodine pentoxide column 5 cms. After the usual preparation and thermal treatment, the blanks from this tube were so low that we were unable to measure them on a 20 litre sample —*i.e.*, they were less than 0·2 parts per million at 120° C.

Simultaneous tests were made with this tube and with our usual apparatus, but unfortunately the new tube gave lower CO figures both at low concentrations of 3 and 28 parts per million and with a richer mixture of 100 parts per million, using a sampling rate of 1¼ litres per hour. Further, when one of our usual tubes was placed beyond the small tube and its absorber, the CO necessary to complete the balance was oxidized, and appeared in the second train. Roughly speaking, 30 p.ct. of the CO escaped oxidation in the small tube. It was plain that in this experiment we were employing too little iodine pentoxide for efficient reaction under the conditions of the test.

We therefore tried this coarse grade of iodine pentoxide (20 to 30 mesh) in one of the large tubes as used hitherto for the fine material. The sampling rate was kept between 1 and 1¼ litres per hour and very satisfactory blanks were obtained, averaging 0·3 parts per million. When this tube was applied to the determination of CO at a concentration of 128 parts per million, side by side with a test conducted in our usual train, the result was just perceptibly low because a small amount of CO could be detected by a second train beyond the coarse tube. The margin of safety for a reliable determination was therefore small, and a medium grade of iodine pentoxide (30 to 50 mesh I.M.M.) was prepared in a similar manner and tested in the large tube.

The blanks for the medium grade of iodine pentoxide (30 to 50 mesh) usually lay between 0·2 and 0·7 parts per million, with an average of 0·4 parts per million. The blank appears to be slightly affected by the sampling rate between 0·5 and 3 litres per hour, but the fluctuation is too small to be important.

From the above statement it is clear that the higher blanks which we formerly obtained were due to the use of a very finely divided iodine pentoxide, and not to any inherent defect in the material used.

When carrying out our later experiments on iodine pentoxide blanks, we obtained a number of results that were unaccountably high—about 7 parts per million—for carefully prepared material. In the course of a few days the blank fell to a normal value again, and the trouble was eventually traced to new black rubber tubing which had been used for renewing connections throughout the trains. This point is mentioned because the renewal of rubber connections is a matter that may require frequent attention. The trouble may be due to solvents used in the manufacture of the tubing (see Fifteenth Report for the effects of benzene vapour and other hydrocarbons on iodine pentoxide).

VIF.—REACTIVITY OF IODINE PENTOXIDE AND RATE OF WORKING.

Some information respecting the reactivity of iodine pentoxide towards small quantities of CO was given in the previous section when stating the reasons for discarding the smaller iodine pentoxide tube and rejecting the coarse 20 to 30 mesh iodine pentoxide in favour of the medium 30 to 50 mesh size.

The fine material used in our earlier work had been tested with mixtures containing CO at concentrations of 250 and 1400 parts of CO per million of sample, and the reaction was quantitative at the highest rate we could then attain in the apparatus, 1·2 litres per hour (Fifteenth Report). A positive result was also invariably obtained both with the air of the test room and with the outside air.

The medium 30 to 50 mesh size finally adopted has been tested at a number of concentrations covering the range met with in the flue gases from our gas fires. Each mixture was drawn through two trains in series, with a potassium iodide absorber and potash bottle between the two trains. Any iodine collected from the second train (when corrected for potassium iodide and iodine pentoxide blanks) was therefore due to CO escaping from the first train and being oxidized in the second iodine pentoxide tube.

It will be observed in the table following that the amount of iodine collected in the second absorber does not increase appreciably until the concentration of CO shown by the first tube is greater than 150 parts per million and the rate of sampling is increased to 3 litres per hour. Below these limits of concentration and rate of working one tube of the 30 to 50 mesh iodine pentoxide will suffice, and no advantage results from increasing the number of tubes.

The "blank" is regarded as the value registered by the second tube when the purest air available—*i.e.*, that drawn from outside the building, is passed through the two trains

* The formula deduced from our tests was:

$$\left.\begin{matrix}\text{Back pressure}\\ \text{(in. w.g.)}\end{matrix}\right\} = \frac{(\text{Mesh no.})^2 \times \text{length (cm.)} \times \text{litres per hour.}}{128{,}000 \times \text{area of cross-section of tube (sq. cm.)}}$$

Reactivity of 30 to 50 Mesh I.M.M. Iodine Pentoxide.

Source of CO.	Rate in Litres per Hour.	Concentration of CO in Parts per Million Shown by		Blank.	2nd Tube *minus* Blank.
		1st Tube.	2nd Tube.		
Outside air (av.) .	1·2	3	0·4	0·4	0·0
Air of room . .	1·3	5	0·6	0·4	0·2
	1·3	8	0·3	0·4	−0·1
	1·0	13	0·6	0·4	0·2
	1·0	24	0·6	0·4	0·2
Flue gases . . .	2·0	48	0·4	0·4	0·0
	2·6	160	3·3	0·4	2·9

in series. When doing this the first tube has always shown a small but definite amount of CO, and the reagent may therefore be regarded as satisfactory for the determination of the amount of CO added to the air by the operation of gas appliances.

With the above arrangement of apparatus we detect any CO passing the first train. If, however, a rate of 2½ to 3 litres per hour is used, and especially if the room temperature is much above 65° Fahr., there may be appreciable loss of iodine from our simple potassium iodide absorbers. This is not disclosed in the above tests, because iodine escaping from the absorber attached to the first train would be stopped by the potash immediately following. Tests on measured quantities of CO using our "drip apparatus" would reveal the deficiency.

VIg.—Carbon Monoxide in Air (Outdoor).

In the Fifteenth Report it was indicated that CO might be regarded as a normal constituent of town air, and that its amount varied with the type of district, the season of the year, and the strength and direction of the wind.

The values for the Meadow Lane district of Leeds appeared to range between 3 and 6 parts of CO per million, with an average value of 4·5 parts per million, but much higher figures were obtainable during fog—25 parts per million being recorded on one occasion. It was pointed out (*loc. cit.*) that the tests in question were made in the colder months of the year (November to March, 1925-26), and might be expected to be somewhat above the average for a complete year.

Opportunities have occurred for further tests, and air drawn directly from outside has been used for the special experiments with iodine pentoxide recorded in Section VIe, and also for the periodic tests of the condition of the reagent, interspersed among the gas fire tests. During the summer months some exceptionally low values were obtained, 1 to 2 parts per million, but CO could always be detected in a 20-litre sample of air. A reduction of the CO concentration is probably characteristic of the summer months, but the drop may have been exaggerated this year (1926) by enforced reduction in fuel consumption during the coal strike. The higher values were again obtained in the period November to March, 1926-27.

For this district, therefore, (Meadow Lane, Leeds—a typical industrial centre) we should regard 1 to 4 parts of CO per million of air as normal summer values, and 3 to 6 parts per million as normal winter values. Values greater than 6 parts per million would require explanation.

The amount and fluctuation in the CO content of the outside air is thus sufficiently great to require consideration when dealing with gas appliances evolving only minute quantities of CO, especially if the samples of chimney gases collected show a high dilution factor.

VIh.—Carbon Monoxide in Air of Test Room.

The air of the test room has invariably shown a higher CO content than that drawn from outside the building, but it must be pointed out that the methods used are extremely delicate and that the highest value given for CO in the air in any of the tests (28 parts per million) is in reality a small and perfectly innocuous amount. So far as the testing of gas fires is concerned, however, it is far from negligible, and in the next Section (VIi) it is shown in what way allowance can be made for the accidental presence of this CO. The only effect upon our work has been to render imperative what would in any case have been advisable—namely, the simultaneous determination of CO in the air of the room and in the chimney gases from the gas fires.

We are unable to say whether the figures shown are typical or excessive, but have spent considerable time in trying to locate the sources of the CO and in attempting to bring about a reduction in the amount, so that we might be assured that the tests had not been adversely affected by unusual conditions in the testing room. For example, comparative tests upon the air of the room made before and after the removal of all volatile chemicals indicated that no trouble arose from this source. All gas fittings in the room were overhauled with the utmost care, and an improvement was effected, but the drastic step of severing all gas pipes leading to the room still left a CO figure well in excess of that in the outer air. A few satisfactorily low values were obtained during the summer months, but with the autumn and winter the value rose again, averaging about 16 parts of CO per million of air.

After a time, sufficient evidence was collected to show that much of the CO was derived from air coming up the staircase shaft from the lower parts of the building, and this air was diverted from the staircase by installing a special ventilating shaft. The CO in the air of the room then fell to 8 or 9 parts per million—*i.e.*, only about 5 parts per million in excess of that in the outside air. The matter was discussed in the Fifteenth Report, where the evidence was decidedly against the suggestion that the CO in the air of the room was derived from the gas fires under test.

The position is, therefore, that while the presence of this CO in the air of the room has been an inconvenience, and has necessitated extra work, the final results when corrected in the manner we describe are not affected in any way by these peculiar conditions.

VIi.—Correction of Results for Carbon Monoxide and Carbon Dioxide in the Air of the Test Room.

When making tests upon the products of combustion from gas fires it was found that under the conditions of experiment the concentrations of CO and CO_2 in the chimney gases were frequently so low that it became necessary to determine and take into account the small amounts of CO and CO_2 in the air near the fire, even when approximate results only were aimed at.

It has already been mentioned that the normal amounts and fluctuations in the CO and CO_2 contents of the air out of doors are sufficient to require attention. It may very well happen, as in the case of our own investigations, that the concentration of CO in the air of the test room, while still well below any limit that might be considered harmful, is, for various reasons, higher than that in the outside air. The difficulty is then accentuated, and it becomes necessary to decide how this adventitious CO should be treated and what corrections should be applied to eliminate error on this account. The notes which follow amplify those given in the Fifteenth Report, under the heading "Method of Calculating Results."

In the case of a modern gas fire properly connected to a flue, it is practically certain that none of the CO in the air of the room is derived from the fire under test. Clearly then, such CO as may be found in the air should be deducted from the total amount found in the flue gases, to obtain a correct value for that produced by the fire. Similar arguments apply to CO_2 in the air of the room, brought in by ventilating air or produced by the breathing of persons remaining in the room during tests. After allowing for such CO and CO_2 in the air, the corrected values obtained for CO and CO_2 in the flue gases should be identical with those obtainable by a more favourably placed experimenter working in pure air.

A hypothetical case requiring consideration is that in which the CO (and CO_2) in the air of the room is derived *wholly* from the appliance burning under the conditions of the test. It may range from an unimportant leakage round the canopy of a gas fire, to the discharge into the room of the whole of the products of combustion, as in the case of the flueless heater, a gas ring, or a lighting burner. The peculiar feature in this case is that the CO and CO_2 in the air of the room, though vastly diluted, will nevertheless have the same *ratio* as in the products of combustion.

The first operation in our experimental work is, in effect, the determination of the ratio of CO to CO_2 in the flue

gases. If the conditions just mentioned are fulfilled, this *ratio* remains unaltered whether we deduct the CO and CO_2 in the air from their respective totals in the flue gases, or whether we make no such correction; and the value obtained for the amount of CO produced per unit of gas burned will be the same in either case.

Most conditions met with in practice will be intermediate between those described above, but generally speaking it will not be practicable to distinguish in the air of the room between CO (and CO_2) derived from the appliance under test and that present from other sources. A correct result can, however, be obtained by deducting the *whole* of the CO and CO_2 in the air of the room, since the inclusion in the correction of that part of it which was derived from the appliance does not affect the CO : CO_2 ratio in the true products of combustion.

The general expression to be used, based upon a complete carbon balance, is therefore:

$$\text{Dilution factor, } p = \frac{CO_2 \text{ from combustion of unit vol. of gas}}{(CO + CO_2)_{\text{in sample}} - (CO + CO_2)_{\text{in air}}}$$

All concentrations in the above expression must be in the same units (*e.g.*, in percentages or in parts per million) and p represents the combined volume of products of combustion and excess air per unit of gas burned.

The production of CO per unit of gas burned is given by

$$p \times (CO_{\text{in sample}} - CO_{\text{in air}}).$$

The figure thus obtained should be characteristic of the appliance and should not be influenced by peculiarities of the testing installation.

It may be argued, however, that the toxic properties of flue gases are determined by the actual concentration of CO found in them, and that it is not permissible to make any deduction for CO and CO_2 in the air accumulated by the previous or continued operation of the appliance, or even for that which has not been derived from the appliance. This view assumes considerable importance when dealing with such matters as the operation of geysers in small bathrooms, or of gas cookers in badly ventilated sculleries. Both the uncorrected and corrected values are then required; the former in reality constituting a test of the complete installation, the latter a test of the appliance only. Given the corrected rate of CO production, however, the limiting CO concentration can be calculated for any assumed conditions of ventilation or period of operation of the appliance.

There is good reason for believing that if the CO_2 content of the air of the test room increases to 1 p.ct. or more (and this will usually be accompanied by a diminished oxygen content of the air) there is a specific increase in the output of CO by the appliance. It is, therefore, not permissible to conduct tests in a badly vitiated atmosphere, and to assume that the results, when corrected in the way we have described, will be identical with those made in a pure atmosphere. In the case of the gas fire tests given in this report, the CO_2 concentration has always been below 0·1 p.ct., so that disturbance from this cause is inappreciable.

Prof. J. W. COBB, in introducing this report said: This report deals with the results obtained in one branch of the work which has been carried out during the past twelve months by the Research Sub-Committee. We have been fortunate in that Prof. Smithells has continued to act as Chairman of the Sub-Committee and to display the same active interest in its work as in the past. There has been one slight change in the personnel of the Committee; Mr. Pooley having been replaced by Mr. Copp as the Institution representative. One of our junior assistants, Dr. Monkhouse, has been called upon to take more responsible work as the Research Chemist of the newly-formed Committee on Gas-Works Effluents; and his place has been taken by Dr. Marson. He has, until recently, for the past two years been the Gas Research Fellow. As regards the subject-matter of the report, you will remember that two years ago the Gas Investigation Committee, and later on your own Council, after careful consideration decided that it was very advisable that we, as a Research Committee, should undertake a thorough investigation into the products of combustion of gas-using appliances. It was considered to be useless to do it unless it were done thoroughly and well; and this has been at the back of our minds all the time. Whether it has been done well or not, I am not going to say, but the attempt has been made to do it as well as we possibly could do it. That this attempt has been made I will certainly claim on my own behalf and on that of the Committee, and perhaps more especially on behalf of Mr. Wood, the Research Chemist, and his assistant, Dr. Howarth, who have been directly engaged upon this very exacting work—exacting because of the high degree of accuracy which has to be obtained in the determination of CO if the results are to be worth anything, and also because the determination of this substance is subject to so many controlling conditions that; if a survey is to be carried out of any appliance in such a way that a useful verdict can be returned upon its behaviour, a vast field of work has to be covered.

This leads me to the next point I should like to make before Mr. Wood is called upon to deal with the work in any detail, and that is that we have taken this year the gas fire. Considering that the gas fire is always used in connection with a flue, and produces small quantities of CO, it might be thought at first sight that the time expended and the number of experiments made were unnecessarily large. This, however, I think would be a great mistake. The gas fire is of primary importance as an appliance in general use, and it affords a means of giving a very careful study and survey of the conditions of CO generally in gas appliances. More particularly does it give an opportunity of studying what is in practice one of the most important, if not the most important, variable condition in connection with such appliances. The condition I refer to is that of the immersion of a solid in a flame. The influence of immersing a solid in a flame—and one has to remember the vast number of cases in which a solid of some sort is immersed in a flame—must be studied in detail if the CO problem is to give results of practical importance. In the case of the gas fire, the solid in question is, of course, the radiant; and the influence of the radiant may be studied in various directions. It has been studied, of course, by this Committee and others in connection with the increase that it alone has rendered possible in the radiant efficiency of the gas fire, adding enormously to the percentage of the heat of combustion which can be radiated from the fire. Now, what is the effect of the immersed radiant upon the process of combustion of the gas? In many parts of the radiant, the temperature is high; there must largely be a process of speeding-up of combustion locally by the action of the radiant. On the other hand, it seems to be plain from the results which have been obtained that any kind of immersed solid which so disturbs the flow of the gas as to break up the structure of the flame or to prevent it assuming the normal shape has its effect upon the production of CO—an effect which it was extremely desirable to study, qualitatively and quantitatively. This has been done with great care; and I think Mr. Wood and Dr. Howarth are to be congratulated on the success which has attended their efforts to solve, or partially to solve, a very difficult problem.

There is another point to which I should like to refer before handing over the account of this investigation to Mr. Wood, and that is that at the University of Leeds we have had parallel investigations carried out upon the behaviour of solid fuel in fires; and it is quite plain, on comparing the results obtained with gas fires and with coal and coke fires, that one misconception should be entirely removed. The gas fire is less liable to produce CO than the solid fuel fire, either coal or coke, and produces it on the average in much smaller quantities. I think all that remains for me to say is that the experimental work in connection with this investigation has been entirely carried out in a laboratory provided by the courtesy of Mr. Shapley and the Leeds Corporation Gas Department at their Meadow Lane Works, and that they have readily afforded all the other facilities required. We should like to express our thanks to them for what they have done in this respect.

Mr. WOOD then gave a brief account of the contents of the Seventeenth Report.

Discussion.

Mr. W. J. SMITH (Bolton): It is obvious that some very exact work has been put into this CO question by the Committee. Gas engineers very often have neither the means nor the apparatus to carry out such fine work; and the work of the Committee will indeed be useful to us. The suggestion I want to make is that the Institution should back this work up in a proper and suitable manner, and that sufficient funds should be forthcoming to carry on not only this research, but other very necessary researches for the gas industry. We have to thank those at the Leeds University for their splendid work.

Mr. C. S. SHAPLEY (Leeds): The Leeds Gas Committee is always willing to assist the Institution in its research work, and has been very pleased indeed to place its resources at the disposal of Mr. Wood. As a member of the Investigation Committee, I am, as it were, the policeman of the Institution at Leeds; but I have to report no crime among the staff. Whenever I have visited the research laboratory I have always found Mr. Wood and his assistants assiduously at work among masses of glass tubing and micrometers, and goodness knows what. It all surpasses me; but what I can say is that I have read the report and have followed the work through with interest. There is a mass of valuable data in the report which provide answers to many carping critics; and I commend the report to you as worthy of more than passing attention. I commend it to you for careful study, for thereby you will

realize the amount of useful work that is really being carried out in the course of these investigations.

The PRESIDENT: I understand that Mr. Butterfield is present; and I need hardly inform him that the members of the Institution will be very pleased to hear him upon this most important matter of carbon monoxide.

Mr. W. J. A. BUTTERFIELD: I had not intended to speak, but as you have asked me, I shall be pleased to say a few words. Unfortunately I have not had an opportunity of reading the report right through, but the results seem to me to indicate that the modern gas fire is not a prolific producer of CO, and I should like to hear the Committee's views on the reservation that it is good practice for all such fires to be fitted with flues. This, of course, is the best practice; but I hope the Committee will go farther, and indicate under what conditions gas heating appliances may be used safely without flues. There are rooms which it is difficult to heat in any other way unless you hand them over to the stuffy electric radiator; and I think it would be well to define the best conditions of use of a gas heating appliance without a flue. The proportion of CO shown by these results is not such that one need fear any deleterious harm if the gas fire were properly used in a reasonably ventilated room and the temperature was raised to a degree necessary for comfort, provided the products of combustion were led above the breathing level of the room. Obviously, if anyone sits immediately over the vent from a heating appliance, the carbon monoxide is of such a concentration that some harm might be done; but if you take steps in the construction of the flueless appliance to conduct the products of combustion well above the breathing level of the room, so long as that room is in occupation no considerable proportion of the products of combustion will come down to the breathing level. The extent of the stratification of the air in a heated room is not always appreciated. The density of the products of combustion, not merely on account of the fact that they are warm, but on account of the large proportion of aqueous vapour which they contain, is lower than that of the air, and the products remain at the higher level subject to convection currents. It is well known that the proportion of carbon dioxide at the ceiling level of a gas heated room with a flueless gas heater or a gas furnace is very much higher than at the breathing level. The figures in the report give the ratio between carbon monoxide and carbon dioxide, and you can compute, by a simple analysis of the carbon dioxide in the air, approximately what the proportion of carbon monoxide will be. I should be very much surprised if, with a really well-constructed gas appliance and a reasonably well ventilated room, merely raising the temperature to what is necessary for comfort would result in the carbon monoxide at the breathing level reaching a dangerous figure. I think that appliances of this kind are so extremely useful in promoting ventilation that in many ways they are much more valuable, notwithstanding the production of a small amount of CO, than an appliance which gives no products of combustion, such as the electric radiator. I merely put these forward as suggestions which the Committee might consider with a view to combatting some of the propaganda—which is not, I feel, fully justified—against gas heating appliances in general.

Mr. J. H. BREARLEY (Southport): I will not say that I have read this report right through, but I am filled with admiration at the thorough way in which Mr. Wood and Dr. Howarth are proceeding on this very important investigation as to how carbon monoxide is produced by gas fires. There was a time, some 22 or 23 years ago, when I thought I could solve all these problems in two years; but I soon found how great the subject was, and that patient and very prolonged research was necessary. I hope there are no members of the Institution who feel at all impatient with the speed of work of these Research Committees. They must of necessity proceed with thoroughness. The way the investigator spent all his time last year finding a test for carbon monoxide, one that could be reliably applied to carbon monoxide in minute quantities, when great scientists had ostensibly used thoroughly reliable tests for many years, shows how intricate this subject is. Mr. Wood has now put before the gas and allied industries a test which may with confidence be applied as a carbon monoxide test. We must also be gratified to see that so far as this research goes we have nothing to fear from carbon monoxide from gas fires, subject to the proviso that they are properly applied and ventilated. The carbon monoxide which will be breathed by the occupants of a room will never be anywhere near the danger zone. I should like to support the suggestion made by Mr. Butterfield that the Committee should proceed a little farther and investigate the flueless gas fire. I have no doubt they will do so in time; and we must have patience. I hope also that we shall hear something about ring burners and cookers in connection with this question. Rome, however, was not built in a day; and in expressing our gratitude for the work the Committee are doing, we must appreciate how difficult it is to reach finality in these questions.

Mr. J. P. LEATHER: There is one thing about this report which at first might seem not good, but which, I think, is really a good thing, and that is that actually the report tells us that there is carbon monoxide where a few years ago we were asserting there was none. To assert there is no carbon monoxide anywhere does not count. A negative assertion is nothing like so good as a positive assertion. A negative assertion simply means that you have not found it. In this case we have a positive one, accompanied by a means of testing. I do not know whether it is perfect or not. I should be a little bit doubtful whether it is perfect in one sense—*i.e.*, there will be possibility of a *plus* or a *minus* error—but at the same time we have now got something definite, and can say that there is only so much, which is a great deal better than saying there is none. A positive assertion means a certain amount of knowledge. I felt I would like to put this point because some people in reading the report might think we were going back in admitting there is carbon monoxide when previously we had always said there was none. At the same time, I would like to support a good deal of what Mr. Butterfield has said.

Mr. C. F. BOTLEY (Hastings): Appreciation has been expressed for this and other research work being done for us at Leeds. If that appreciation is really felt, then, if we are going to ask for funds in any way presently, I hope all those who have or have not testified to the value of the work will not fail us. Though it is true there are means by which a certain amount of money is forthcoming at the present time, it has been said over and over again that it is quite inadequate; and this research work must be conducted by the Institution.

One always feels diffident in attempting to offer observations on a report of this highly technical nature, because one may inadvertently "put one's foot in it" through being ignorant; but there are one or two points which arose in my mind when Mr. Wood was giving his summary of the report. I hope he will correct me if I have in any way misconstrued or misunderstood him, because I have not had time to follow up the points in the report. First of all, I notice that he said—and it seemed to me to be in relation to some legislative proposal—that the amount of carbon monoxide in the resultant products of combustion was independent of the carbon monoxide in the orginal gas. I venture to say this is a very important pronouncement, and will not, I hope, be lost sight of. He also pointed to the considerable difference in the carbon monoxide content in the products of combustion with the variation of the rate of gas used in the fire. He also makes the point which does not follow, that the highest degree of purity in the products—*i.e.*, the absence of carbon monoxide—is in accordance with the best effect thermally of the fire. That is to say, when the fire is burning to the best advantage, the products in regard to carbon dioxide may be higher than otherwise would be the case. Perhaps Prof. Cobb emphasized this point when he mentioned that we have a flame, and that as soon as we introduce a solid substance into it, and vary the size of the flame, we affect the products of combustion; and I could not help thinking, when the Professor was speaking, that if we were to test the results of the introduction of every solid into a flame, we should have more than a life's work. One other point. We have often felt, when we have seen flames scaling above the tops of the fuel or radiant, that there has been a great deal of loss going on; but apparently—here again I may have misunderstood—the carbon monoxide content of the products of combustion is not affected. I should like to ask Mr. Wood whether he did consider the carbon monoxide produced in that case, or whether he took into account the probable higher aeration which would be produced by that excess heat going up a flue, which would, of course, tend to reduce the percentage of carbon dioxide in the products of combustion, owing to the greater amount of air or products going up the chimney. There are many other points to which one would like to call attention; but time is short. I do hope, however, that the appreciation that has been expressed of the work being done at Leeds will be translated into practical form when the question of funds comes up presently, and that you will all back us up.

Mr. J. FERGUSON BELL (Derby): I should like to express on behalf of myself and the Institution generally our great indebtedness to the Research Committee for the very important work that is being carried out at Leeds. I do not propose to criticize this report, especially in the presence of our friends Prof. Smithells and Prof. Cobb, who, I am sure, we are all glad to see here this morning; but there is one point which has been made, I think by Prof. Cobb, when he stated that the gas fire is less liable to produce carbon monoxide than the solid fuel fire. I think that is a very important matter which should be borne in mind. It cannot be too well known, because there is sometimes a dread in the minds of users of gas fires with reference to this question of the production of carbon monoxide. While I am expressing appreciation of the work of the Research Committee, I think we might, as engineers, congratulate the makers of gas fires on the enormous advance they have made during the past few years. I think a word of encouragement is due to the manufacturers, because, in the course of only a few years, there has been an enormous advance. In fact, gas fires have now reached such a state of perfection that we need have no fear or hesitation in fixing them anywhere. I often hear it said by people in my own town that they have had gas fires in the past, and have removed them, but have since gone back to them, to find them a real comfort and a pleasure. I only hope that the work of this Committee will continue. The note that Mr. Butterfield

sounded is well worthy of investigation, because there are places where we cannot always fix a flue, though I make it a practice to fix one wherever possible, not only to take away the products of combustion, but to help in the ventilation. Nevertheless, there are places where it is impossible to fix flues; and this is a point into which the Gas Investigation Committee might continue their inquiries to see what kind of gas fire could be used for heating premises where there is a reasonable amount of ventilation but where it is not possible to fix a flue. I join the other speakers in expressing our indebtedness to the Gas Investigation Committee for the work they have carried out.

The PRESIDENT: I do not want to curtail discussion on this report; but if there are no other speakers, it will be necessary for me now to call upon Prof. Cobb and Mr. Wood to reply. If there are several other speakers, we will adjourn the discussion until after lunch.

There being no other speakers,

Prof. COBB said: I should simply like to say on behalf of Prof. Smithells and myself how pleased we are to hear such appreciative comments from members of the gas engineering profession who are accustomed to deal in practice from day to day with the problems which we investigate mainly in the laboratory. As regards the questions that have been raised, I will ask Mr. Wood to deal with them.

Mr. WOOD: Of the technical points that have been raised, the first was mentioned by Mr. Butterfield. If we take a flueless heater and examine the contamination of the atmosphere with time, starting with a perfectly pure atmosphere and lighting up the fire, the percentage of carbon monoxide and carbon dioxide rises gradually so that at the end of a short time we have very nearly reached the maximum contamination of the atmosphere likely to occur with a given degree of ventilation; and we had hoped that in the form in which the figures are given in the report, the final state, the maximum, could be calculated by multiplying the rate at which carbon monoxide was produced per cubic foot of gas burned by the gas rate, divided by the ventilation. The only trouble that arises there is the real one that Mr. Butterfield points out—viz., that calculations of this kind assume uniform mixing, whereas observations in practice show that there is definite stratification. Turning to Mr. Botley's remarks, I did make the statement that we could expect no simple relation between the amount of carbon monoxide originally in the gas and that appearing in the products of combustion. I think the amount of carbon monoxide will depend upon the amount of carbon present—the carbon concentration in the gas—and the temperature of the flame. The other important point which was raised was the matter of aeration as affecting carbon monoxide and efficiency. You have to remember that to obtain satisfactory heating of the radiant you must get a flame which will fit the radiant. If you can do that, by increasing the size of the flame or altering its shape, and getting a better fit by cutting down the degree of aeration, the total amount of heat radiated into a room is better, despite the loss of a small amount of gas as carbon monoxide, than by working to the minimum amount of carbon monoxide. The other point raised by Mr. Botley was the question of the flame burning above the radiant and giving a higher flame temperature, and consequently a higher degree of ventilation, which ought to lead to a reduced carbon monoxide production. Actually, you ought to expect the quantity of carbon monoxide to come down in the flue gases themselves; but when you calculate back in the way we have done, you eliminate the effect of excess air, and therefore the figures we give in the report still stand.

The PRESIDENT: I had made a number of notes upon points which I wished to raise, but they have been dealt with by previous speakers; and I will therefore without further comment ask you to approve the report in the usual manner.

The report was then adopted.

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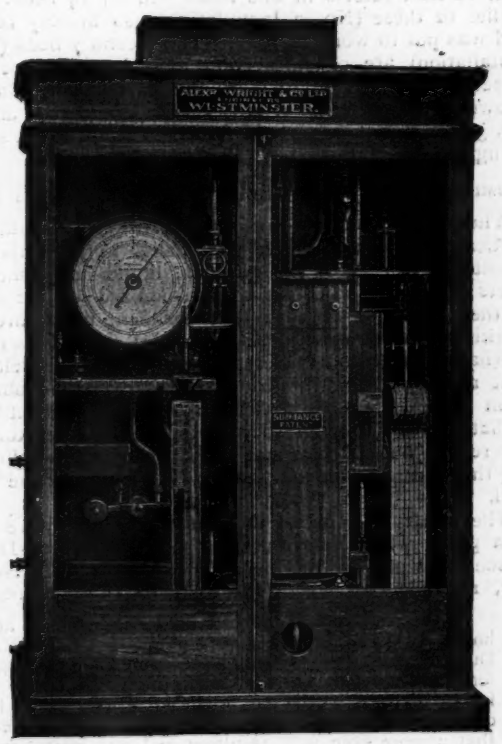

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MODERN CARBONIZING ECONOMICS EXEMPLIFIED BY RESULTS AND WORKING COSTS AT THE PORTSMOUTH GAS-WORKS.

By THOS. CARMICHAEL, M.I.Mech.E., of Portsmouth.

General Introduction.

The author proposes to limit his remarks to the carbonizing plant and methods employed by the Portsmouth Gas Company, giving results and working costs which may be strictly comparative among themselves, and at the same time giving sufficient detail as to labour employed, rates of pay, &c., to make these figures as useful as possible when compared with those obtaining at other works.

The Company's manufacturing plant is divided between two of the three stations. At Flathouse, the oldest of the stations, shown in plan in fig. 1, there are 10 beds of Woodall-Duckham continuous vertical retorts erected in 1915-16 (referred to later as No. 1 Installation), 9 beds of 9 horizontal retorts, and two carburetted water gas plants, each of one million c.ft. capacity. There is no railway communication with this station; coal being brought in by sea to the Company's quay adjoining the works, and there unloaded into store by a 5½-ton steam grabbing crane and a system of band conveyors.

Hilsea Works, a considerable distance from the sea, has railway sidings from the main line of the Southern Railway. Up to 1920 there were here 20 beds of 9 horizontal retorts, and two 1-million c.ft. carburetted water gas sets.

Owing to the rapidly increasing demand for gas, indicated by the curve in fig. 2, it was necessary to put considerable extensions in hand soon after the war. Since 1919, therefore, additions have been made at Hilsea, comprising, first, the reconstruction of the horizontal house, which has been remodelled to 20 beds of 10 retorts, and, secondly, the erection of two benches of Woodall-Duckham vertical retorts in one house—in all 14 beds. The earlier of these (No. 2 Installation) has fireclay retorts, and was put to work in 1921. The second 7 beds (No. 3 Installation) are of silica, and have been in operation since 1925. The lay-out of the carbonizing plant is shown in the part plan of Hilsea Works in fig. 3, and the No. 3 Installation of vertical retorts in longitudinal section in fig. 4.

Elimination of Fines and Dust from Durham Coal.

The importance of working *existing* horizontal and vertical retorts and water gas plants to yield the best results in respect of the gaseous, liquid and solid products obtainable from the coal carbonized led the author in the early part of 1922 to experiment under ordinary working conditions with screened and partially screened Durham gas coals of average quality. It was felt then that much better carbonizing results might be obtained from the existing old pattern (No. 1) vertical retort installation, not only in thermal production per ton and per retort, but in coke and liquid products, by eliminating the dust and fine coal, and carbonizing only the larger coal.

The results of some of these investigations were given in a paper which was read before the Southern District Association of Gas Engineers and Managers in November, 1922, and of which the following is an extract:

> In this connection one bed of vertical retorts at Flathouse was working for a considerable period on screened Durham coal; the coal being screened by hand and separated for this individual bed. Although it was impossible to isolate or measure the gas produced, it was proved beyond doubt that the throughput could be materially increased; that a more even pull, resulting in lower inerts, could be maintained at the top of the retort; and that considerably less trouble was encountered through the hanging-up of the charge.
>
> From this it may be presumed that, if screened Durham coal could be used throughout, labour costs might be reduced and also probably wear and tear on the retorts. So obvious are these advantages that a screening plant is now being installed in connection with our main coal conveyors, so that the unscreened Durham coal received from the ship is to be immediately separated, the screened portion going on to the vertical retort house stores and the screenings dropping down for use in the horizontal house. A photograph of the screen erected in the shops is here given.

[See "GAS JOURNAL," Vol. CLX., p. 558.]

The elimination of the dust and fines from the unscreened coal as received was commenced in December, 1922, and the anticipated results from the use of screened and partially screened Durham coal have been fully realized. In using the larger coal in the No. 1 Installation of vertical retorts, improvement has been found in every direction; the actual increase in the thermal output of the coal being 10 p.ct., and of the plant 20 p.ct., and less sticking of the charge has been experienced.

The production per ton of coal carbonized rose from about 62 therms with the unscreened coal to 69·1 with the screened coal, while in the horizontal house the total therms evolved from the smaller grade of fuel dropped only to 68·8 per ton as compared with 70·2 from the unscreened variety.

When the thermal output of the plant is also taken into consideration, the improvement is more marked. Thus the output of one bed of vertical retorts rose from 860 to 1032 therms per day, while owing to the large proportion of fines in the unscreened coal the throughput of the horizontals was practically the same with the screenings as with the through coal.

From the experience gained since 1922 at the Flathouse Station, it is unquestionably good carbonizing practice, where continuous verticals and horizontals are in existence and where the principal supply of coal contains a large percentage of fines—as most Durhams do—wholly or partially to screen the coal for use in the vertical retorts, and to carbonize the smalls in horizontal retorts.

A further conclusion from these experiments is that, with the exception of coal—particularly swelling coal—containing a high proportion of dust, there are few coals, if any, that cannot be carbonized satisfactorily in vertical retorts. Coal dust is a bad conductor of heat; and this renders a dusty coal anything but the most suitable for vertical retorts and steaming. There is a falling-away in such cases from the high standard of efficiency realized with vertical retorts and steaming when using a coal comparatively free from fines.

Four typical samples of the through coal were separated into the following average grades:

Grade.	P.Ct. Weight of Coal.	Ash Content. P.Ct. Dry Basis.
Over 1 in.	25·5	7·1
½ in. to 1 in.	21·1	7·5
¼ in. to ½ in.	18·3	7·2
Below ¼ in.	35·1	11·5

The position of the screen is indicated in fig. 1, and the screen itself—a bar screen which has replaced the original rotary machine—is shown in fig. 5.

The influence of the size of coal in carbonization is deserving of much more detailed study; and both the Sixteenth Report of the Gas Investigation Committee and the paper by Mr. T. F. E. Rhead presented to the Institution last September give much valuable information on this subject.

Effect on Quality of Coke.

The experience of a number of years has proved that coke from vertical retorts is a more readily saleable fuel than that from horizontals. The characteristics of the former fuel which influence this are chiefly:

(*a*) Lower moisture content, and therefore
(*b*) Lighter and more easily ignited fuel.
(*c*) Better appearance.

It is unnecessary here to emphasize the importance of doing everything possible to retain the coke market,

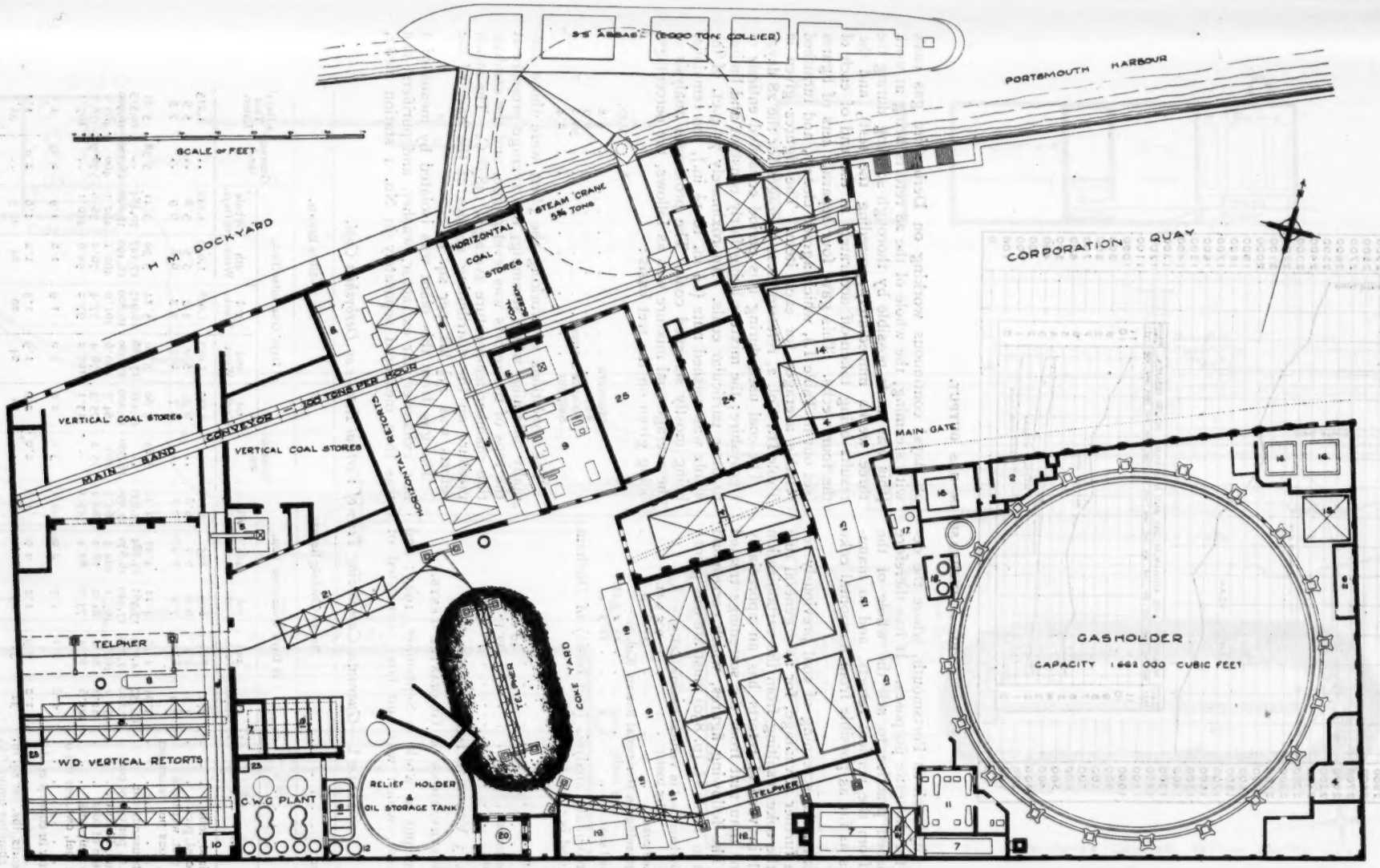

FIG. 1.—PLAN OF FLATHOUSE GAS-WORKS.

PLAN OF FLATHOUSE GAS-WORKS.

1. Coke Office.
2. Office (Laboratory over).
3. Weighbridge.
4. Stores.
5. Elevators.
6. Band Conveyors.
7. Lancashire Boilers.
8. Waste Heat Boilers.
9. Power House.
10. Extractor Engine House.
11. Exhauster House.
12. Condensers.
13. Washer Scrubbers.
14. Purifiers (Coal Gas).
15. Purifiers (C.W.G.).
16. Station Meters.
17. Governor and Booster House.
18. Sample Holders.
19. Tar, Liquor, and Water Tanks.
20. Deep Well and Water Tower.
21. Coke Hoppers.
22. Breeze Hoppers.
23. Lift.
24. Fitters' Shop (Joiners' Shop over).
25. Smithy (Mess Room over).
26. Latrines.

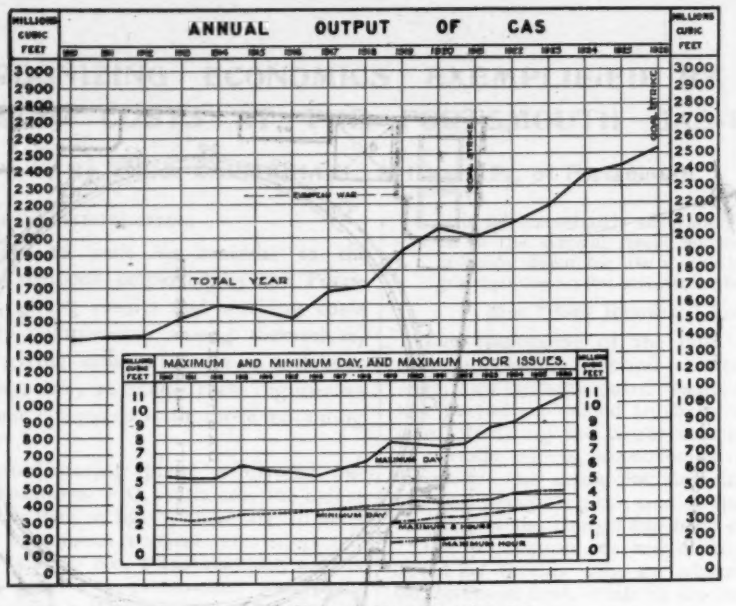

FIG. 2.—INCREASE IN GAS OUTPUT.

particularly in a city such as Portsmouth, where the demand is largely for domestic purposes. It has therefore been the established practice to sell the whole of the output of coke from the vertical retorts, and to manufacture water gas as far as possible from horizontal coke only.

In this connection the screening of coal previously referred to offers a further advantage, for as a general rule it is found that the coke resulting from the carbonization of screened coal in vertical retorts has an appreciably lower ash content than that from the screenings treated in horizontals. The following figures, which correspond to the tests given in Table II. (p. 850) illustrate this point:

(i.) Screened Durham Coal in Vertical Retorts (Col. 5)—
Ash in coal (dry basis) . . . . . 9·2 p.ct.
Ash in screened coke ,, ... 11·6 ,,

(ii.) Durham Screenings in Horizontal Retorts (Col. 9)—
Ash in coal (dry basis) . . . . . 13·2 p.ct.
Ash in screened coke ,, ... 16·3 ,,

An average proximate analysis (wet basis) of Durham gas coal as received is:

	P.Ct.
Moisture	2·7
Ash	10·2
Volatile matter	30·1
Sulphur	2·3

No. 3 Vertical Installation.

General Observations on Guarantee Tests.

This plant was put to work in September, 1925; and the guarantee test, which was run later, consisted of 28 days' continuous working on Derbyshire gas coals with steaming, the whole of the 28 retorts being at work (this was made possible by thorough scurfing during the three weeks immediately preceding the test), and the results being taken-off accurately at the end of each of the four weeks. This gave four separate sets of figures (set out in Table I.), which agreed closely, and furnished reliable averages for each item. The figures given in Table II., Col. 2, refer to these averages for the 28 days.

The coal used during this period consisted entirely of Derbyshire; the mixture being fairly constant and limited to three particular coals. Approximately 75 p.ct. of the whole was washed nuts (1¼ in. to 1½ in.), the remainder being mostly screened coal. The proximate analysis of the average coal mixture was as follows, the percentages being given on the wet basis:

	P.Ct.
Moisture	5·8
Ash	6·9
Volatile matter	30·2
Sulphur	2·4

The conditions of working the plant were those normally obtaining while steaming, the average pressure at the tops of the retorts was level gauge, and the combustion chamber temperature averaged 1383° C. The steam pressure on the distributing nozzles at the base of the retorts was 23½ lbs. per sq. in.

The gas from this plant was isolated by means of a new exhauster, tar extractor, washer, and purifiers, and was then measured separately in No. 1 station meter,

TABLE I.—*Guarantee Carbonizing Tests of Vertical Retorts on Derbyshire Coal.*

Installation	No. 2—Glenboig Retorts.						No. 1—Silica Retorts.						
Test	28 Days' Guarantee Test.					Guarantee.*	28 Days' Guarantee Test.					Guarantee.*	8-Days' Test Later.
Period	1st Week.	2nd Week.	3rd Week.	4th Week.	Whole 28 Days.		1st Week.	2nd Week.	3rd Week.	4th Week.	Whole 28 Days.		
Coal carbonized, tons	772	816	805	825	3,218	..	1,137	1,057	1,008	1,040	4,242	..	1,213
Moisture in coal, p.ct.	6·5	7·2	6·0	6·7	6·6	..	6·3	5·9	5·5	5·5	5·8	..	5·9
Ash in coal, p.ct. wet basis	8·5	8·6	7·9	6·4	7·8	..	6·7	6·7	7·3	6·8	6·9	..	7·5
Throughput, tons per retort per day	3·94	4·16	4·11	4·21	4·10	3·84	5·80	5·40	5·14	5·30	5·41	5·38	5·41
Gas made, thousands c.ft.	13,757	14,035	13,961	13,884	55,637	..	18,426	17,986	16,925	17,147	70,484	..	20,515
Gas made, c.ft. per ton of coal	17,820	17,200	17,340	16,830	17,290	16,390	16,200	17,020	16,800	16,490	16,620	16,720	16,900
Calorific value, B.Th.U.	457·7	469·3	467·2	464·5	464·7	460	464·7	460·6	461·0	462·1	462·1	460	463·0
Therms per ton of coal	81·6	80·6	81·0	78·2	80·4	75·4	75·3	78·4	77·4	76·2	76·8	76·9	78·2
Dry ash-free fuel, tons	101·6	87·4	73·7	82·4	345·1	..	113·1	107·2	97·2	92·6	410·1	..	107·4
Dry ash-free fuel, cwt. per ton of coal	2·6	2·1	1·7	2·0	2·1	3·2	2·0	2·0	1·9	1·8	1·9	2·25	1·8
Volatile matter in coke, p.ct. dry basis	1·2	0·9	1·2	2·0	1·3	2·0	2·0	1·9	1·3	1·2	1·6	2·0	1·4
Steam on retorts, lbs. per sq. in.	32	31	29	25	29	..	26	24	20	24	23·5	..	34·8
Combustion chamber temp., ° C. top	1,214	1,210	1,214	1,225	1,216	..	1,384	1,397	1,368	1,383	1,383	..	1,440
Combustion chamber temp., ° C. bottom	..	..	..	..	..	..	..	..	..	..	About 1,150	..	1,151
Column No. in Table II.	..	..	..	..	1	..	..	..	..	..	..	..	2

* Guarantees were based on dry coal containing 6 p.ct. of ash. Figures here given are corrected to raw coal.

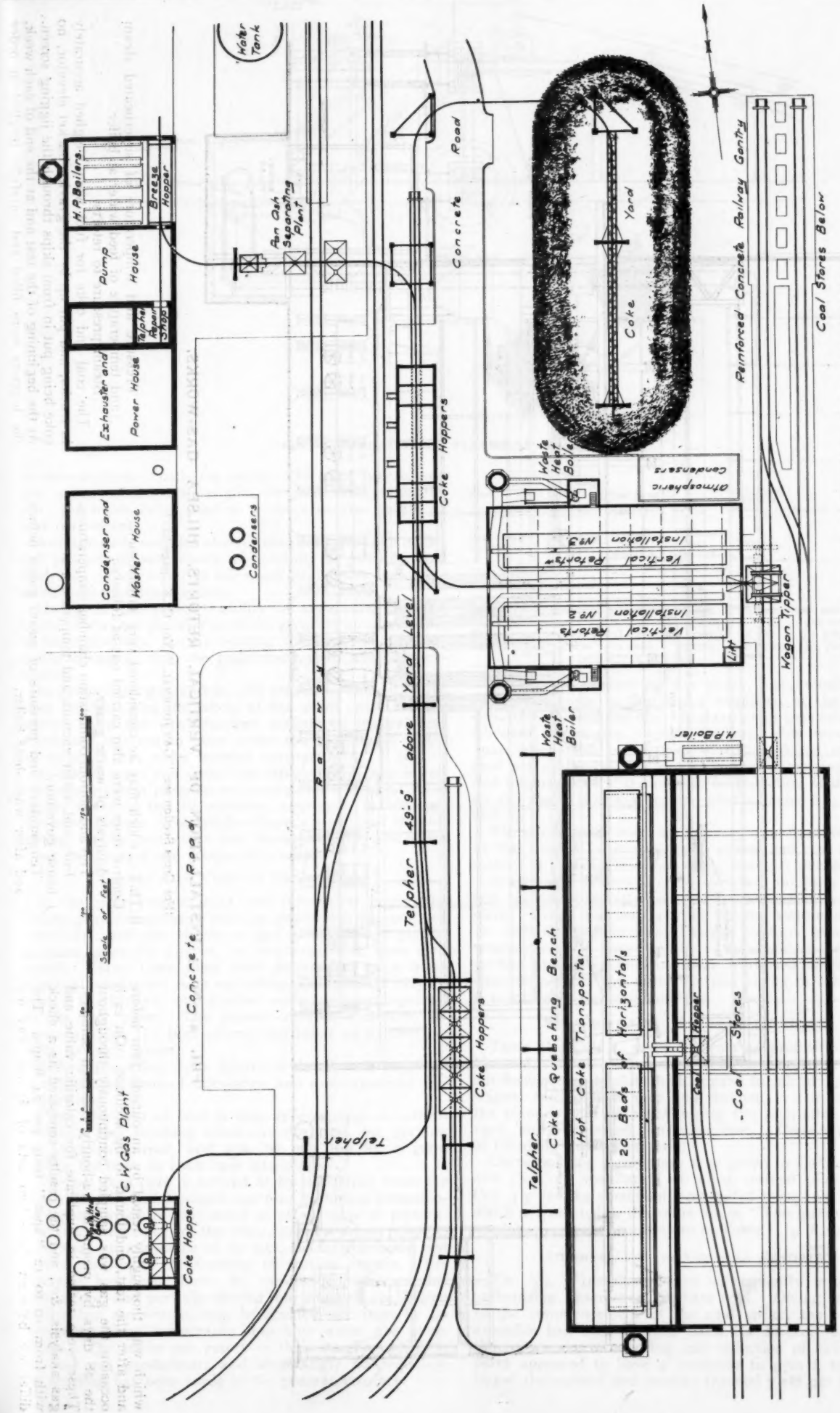

FIG. 3.—PART PLAN OF HILSEA GAS-WORKS, SHOWING CARBONIZING INSTALLATIONS.

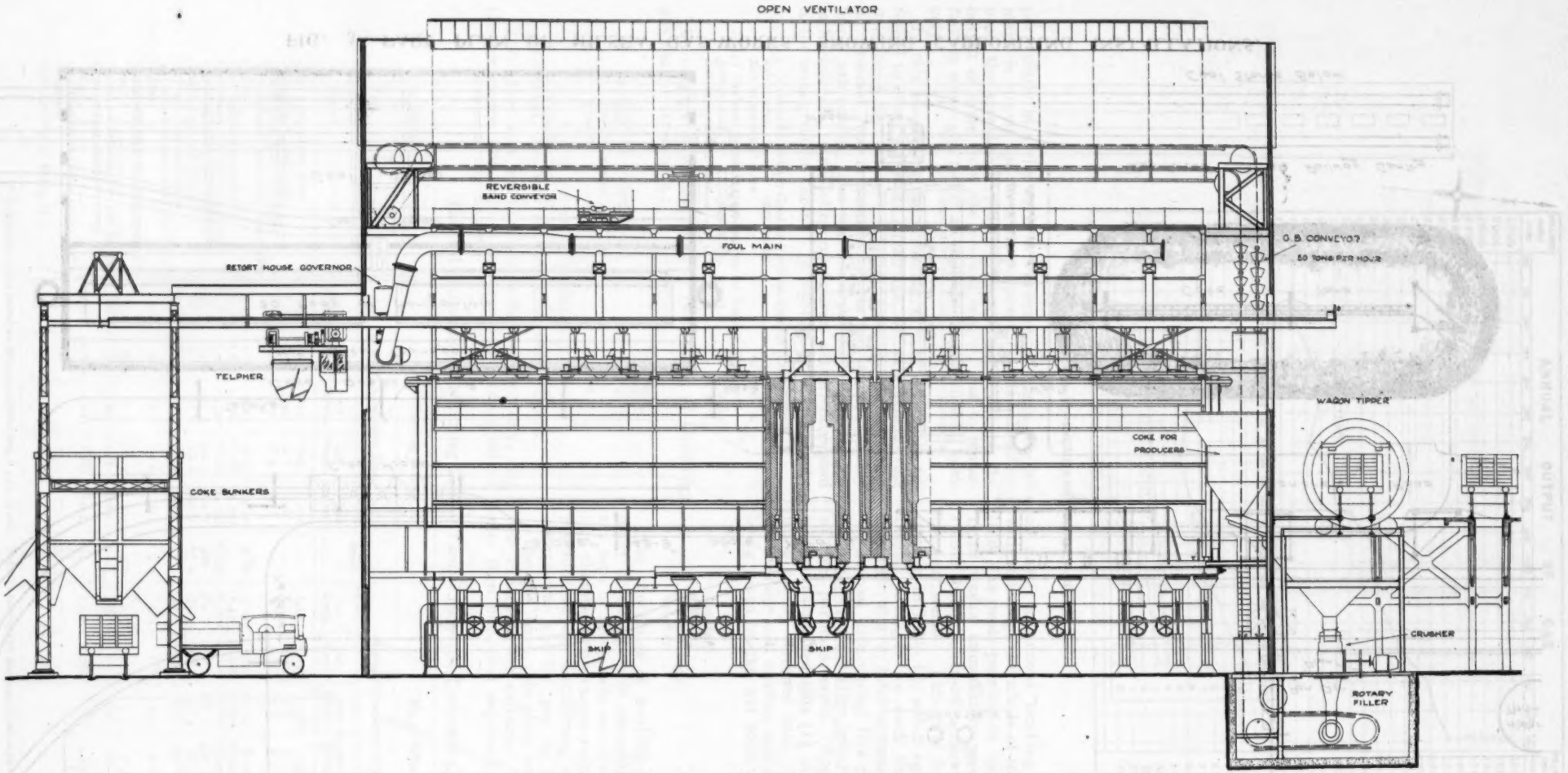

FIG. 4.—No. 3 INSTALLATION OF VERTICAL RETORTS, HILSEA GAS-WORKS.

(For Cross Section see "GAS JOURNAL," Vol. CLX., page 552.)

which was thoroughly tested by an outside firm before and after the test, and found to be accurate. On each occasion the gas was sampled continuously throughout the 28 days by means of 12-hourly collected samples. These were tested in duplicate for calorific value and gas analysis, &c., and the results compared as a check with from 10 to 12 "spot" tests per 24 hours. The difference between these two sets of figures was 0·9 B.Th.U., which may be considered very satisfactory.

Control tests were also carried out as follows:

Analysis of waste gases.

Top and bottom combustion chamber temperatures.

Inlet and outlet vacuum and temperature at retort house governor.

Temperature and pressure of waste gases before and after waste-heat boiler.

Pressure and temperature of superheated steam and temperature of feed water at boiler.

Steam pressure to retorts.

The coal and coke for fuel were weighed accurately in trucks, and put up by the gravity bucket elevator, no coke being put in from skips through the jigging screen. At the beginning of the test and at the end of each week, the hoppers were filled and carefully levelled in order

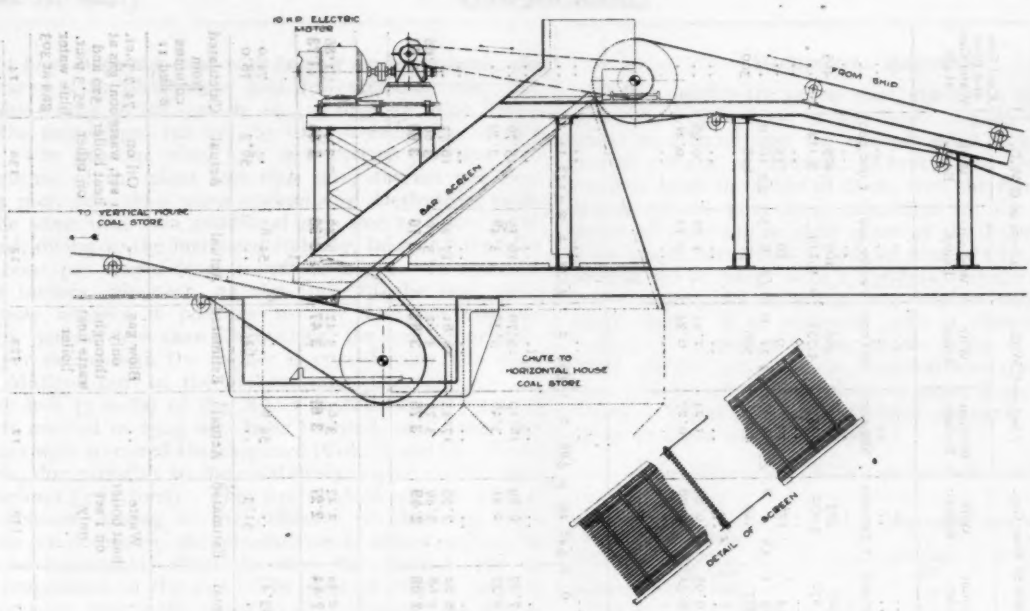

FIG. 5.—COAL SCREEN, FLATHOUSE GAS-WORKS.

to correct automatically for stock. The coke, breeze, and pan ashes produced were also weighed throughout the test; the totals being used as a check on the weight of coal carbonized.

Average daily samples of coal, coke for fuel, coke made, and pan ashes were taken as carefully as possible, and analyzed. Feed water to the waste-heat boiler was measured in a tip-bucket meter.

Owing to the impracticability of separating tar and liquor, it was not possible to obtain accurate measurements of these products; but considering the total make of tar, it would appear that the guaranteed yield has been exceeded.

In general the guarantees, also set out in Table I., have been fulfilled; and the whole of the plant (with the exception of a few complications introduced by leakages which are referred to later under the heading of "Refractories") has since worked satisfactorily.

The tests were run under the strictest supervision and with the greatest possible accuracy; and it is upon these figures obtained by the author's assistants, in conjunction with Messrs. Woodall-Duckham's staff, that the following results and costs are based—figures which are being maintained and frequently exceeded.

Calculating Cost of Production.

In the paper read in 1922, and referred to above, the author gave comparative costs of production per ton, per 1000 c.ft., and per therm of gas from various plants. In some cases the figures, as then explained, were estimated. These have since been ascertained on a basis of actual production tests extending over periods varying from 7 to 28 days; and similar work has been repeated on the new plant. The present results, therefore, as given in Table II., both extend and bring up to date the costs formerly given.

Before discussing these figures in detail, it is proposed to explain the basis of calculation and some apparent discrepancies.

First, the cost of coal is that appertaining to current contracts *plus* handling costs—namely, 31s. 6d. per ton for Derbyshire coal, and 25s. 3d. per ton for a good quality Durham, in each case into store.

The net coal cost is arrived at by deducting from the above the value of residuals per ton, excluding ammoniacal liquor, which is considered as of no value at present. The yields and values of the other residuals are as follows:

In 1922 an allowance of 10 p.ct. below guarantee test results was made for scurfing of vertical retorts. Recently it has been shown by various members of this Institution—and partially carried into effect on the Hilsea plant—that the retorts may be scurfed satisfactorily by converting them temporarily into blue water gas generators. The make per retort is then roughly equal to its coal gas production; and accordingly no reduction for scurfing has been made in the present instance.

Plant	Vertical Retorts.			Horizontal Retorts.	Value.
Coal and Conditions	Derbyshire Steaming.	Durham Stock Steaming.	Durham Non-Steaming.	Durham.	
Cols. in Table	1, 2, 3	4	5, 6	7, 8, 9	
Coke	9 cwt.	9⅝ cwt.	10 cwt.	10 cwt.	30s. and 26s. 6d. per ton
Breeze	½ cwt.	1½ cwt.	1 cwt.	1 cwt.	10s. per ton
Tar	15 galls.	12 galls.	10 galls.	10 galls.	4½d. per gall.

During the intervening five years, also, modifications have been made in the labour employed in the various departments, and the cost of labour is in general reduced (though wages are slightly higher). For instance, in 1922 seven beds of vertical retorts employed seventeen men per 24 hours. By re-distribution of leading hands' and telpher drivers' duties, and by reduction of day work on the plant, this has become fifteen (Table II., Cols. 1 and 2).

The labour rates used are in every case those obtaining at the time of writing (April, 1927), and are approximately 2½ p.ct. higher than those formerly detailed.

Waste-heat boilers are in operation on both vertical and horizontal installations and on one set of water gas plant. Credit has been allowed (at the bottom of Tables II. and III.) for the surplus steam produced therein. In steamed vertical retorts (Cols. 1, 2, 3, and 4) the greater portion of the waste-heat steam is utilized on the plant itself to produce the stated thermal yield; in other cases it is available for use elsewhere.

Derbyshire Coal in Vertical Retorts.

Table II., Col. 1, gives the cost of production in the No. 2 Installation of vertical retorts, as given in 1922, but brought up to date with regard to labour employed, wages, and costs of coal and residuals. The output of the plant is that obtained during the guarantee tests in 1921, and maintained since that date. These retorts are of Glenboig fireclay material.

Corresponding figures are now given in Col. 2 for the new (No. 3) installation of silica vertical retorts; and Col. 3 gives the combined working of these two benches, which are erected in the same house. The guarantee test results in each case are set out in Table I. (p. 846).

Durham Coal in Vertical Retorts.

The No. 3 Installation was subsequently tested when carbonizing unscreened Durham coal. Owing, however, to the commencement of the coal strike, the only coal available had been in yard stock for several years, and the consequent weathering and reduction of caking property appeared to have a tendency to give a somewhat larger throughput and smaller thermal yield per ton than

TABLE II. (April, 1927).—*Cost of Production (Carbonizing Only).*

System	W.D. Vertical Retorts.						Horizontal Retorts.			Water Gas Plant.								Mixed.
										1 Set on Blue Gas.		2 Sets on Blue Gas.		1 Set on C.W.G.		2 Sets on C.W.G.		
Plant, Coal, and Conditions	No. 2 Installation, 7 Beds. Derbyshire Steaming.	No. 3 Installation, 7 Beds. Derbyshire Steaming.	Nos. 2 and 3 Installations, 14 Beds. Derbyshire Steaming.	No. 3 Installation, 7 Beds. Durham (Stock) Steaming.	No. 1 Installation, 5 Beds. Durham Screened. Non-Steaming.	No. 1 Installation, 10 Beds. Durham Screened. Non-Steaming.	9 Beds, 8 Hour. Durham Unscreened.	9 Beds, 12 Hour. Durham Unscreened.	9 Beds, 12 Hour. Durham Screenings.	Without Boiler.	With Boiler.	Without Boiler.	With Boiler.	Without Boiler.	With Boiler.	Without Boiler.	With Boiler.	Coal Gas and Blue Water Gas at 465.
Coal carbonized, tons, 24 hrs.	115	151·6	266·6	129·6	74·7	149·4	95·4	81·0	82·1	..	..	..	..	..	..	..	..	..
Throughput or charge	4·1	5·4	4·76	4·63	3·74	3·74	8·1	10·3	10·4	..	..	..	..	..	..	..	..	..
Gas made per 24 hrs., c.ft.*	1,987,000	2,564,000	4,551,000	1,888,000	1,034,000	2,068,000	1,221,000	1,093,000	1,094,000	870,000	870,000	1,740,000	1,740,000	980,000	980,000	1,960,000	1,960,000	..
Gas made per ton, c.ft.*	17,290	16,900	17,070	14,570	13,840	13,840	12,800	13,490	13,330	..	..	..	..	..	..	..	..	..
Calorific value, gross	465	463	463·7	477·5	499·0	499·0	523·5	520·0	515·8	303	303	303	303	465	465	465	465	465
Therms per 24 hrs.	9,240	11,860	21,100	9,017	5,161	10,322	6,392	5,683	5,643	2,636	2,636	5,272	5,272	4,557	4,557	9,114	9,114	..
Therms per ton of raw coal	80·4	78·2	79·2	69·6	69·1	69·1	67·0	70·2	68·8	..	..	..	..	..	..	..	..	..
Number of men per 24 hrs.	15	15	23	17	17½	30	24	20	20	10	8½	14	12½	10	9	16	15	..
Labour cost per 24 hrs.	£7 12 2	£7 12 2	£11 13 8	£8 15 6	£8 19 1	£15 5 10	£12 6 2	£10 5 2	£10 5 2	£5 1 3	£4 5 10	£6 17 1	£6 1 8	£5 1 3	£4 11 0	£8 6 3	£7 16 0	..
Therms per man-day	616	791	917	530	295	344	266	284	282	264	310	377	422	456	506	570	608	300
Cost of labour:																		
Per ton s. d.	1 3·9	1 0·0	10·5	1 4·2	2 4·8	2 0·6	2 7·0	2 6·4	2 6·0	..	..	..	..	..	..	..	..	..
Per 1000 c.ft. d.	0·92	0·71	0·62	1·11	2·68	1·77	2·42	2·25	2·25	1·40	1·18	0·95	0·84	1·24	1·11	1·02	0·96	..
Per therm d.	0·20	0·15	0·13	0·23	0·42	0·36	0·46	0·43	0·44	0·46	0·39	0·31	0·28	0·27	0·24	0·22	0·21	..
Cost of coal per ton s. d.	31 6	31 6	31 6	25 3	25 3	25 3	25 3	25 3	25 3	..	..	..	..	..	..	..	..	..
A.—WITH COKE AT 30S. PER TON.																		
Value of residuals per ton of coal s. d.	19 4	19 4	19 4	19 3	19 3	19 3	19 3	19 3	19 3	..	..	..	..	..	..	..	..	..
Net materials per 24 hrs.	..	..	..	..	..	..	..	..	..	£26 0 0	£22 10 0	£52 0 0	£48 10 0	£66 2 1	£64 2 1	£132 4 2	£128 14 2	..
Net cost of materials:																		
Per ton s. d.	12 2	12 2	12 2	6 0	6 0	6 0	6 0	6 0	6 0	..	..	..	..	..	..	..	..	..
Per 1000 c.ft. d.	8·44	8·64	8·55	4·94	5·20	5·20	5·63	5·34	5·40	7·17	6·21	7·17	6·69	16·19	15·70	16·19	15·76	..
Per therm d.	1·82	1·87	1·84	1·03	1·04	1·04	1·08	1·03	1·05	2·37	2·05	2·37	2·21	3·48	3·38	3·48	3·39	..
Total cost:																		
Per ton s. d.	13 5·9	13 2·0	13 0·5	7 4·2	8 4·8	8 0·6	8 7·0	8 6·4	8 6·0	..	..	..	..	..	..	..	..	..
Per 1000 c.ft. d.	9·36	9·35	9·17	6·05	7·28	6·97	8·05	7·59	7·65	8·57	7·39	8·12	7·53	17·43	16·81	17·21	16·72	..
Per therm d.	2·02	2·02	1·97	1·26	1·46	1·40	1·54	1·46	1·49	2·83	2·44	2·68	2·49	3·75	3·62	3·70	3·60	1·66
Per therm, less credit for surplus steam, d.	**2·02**	**2·02**	**1·97**	**1·25**	**1·40**	**1·34**	**1·41**	**1·34**	**1·37**	**2·83**	**2·44**	**2·68**	**2·49**	**3·75**	**3·62**	**3·70**	**3·60**	**1·53**
B.—WITH COKE AT 26S. 6D. PER TON																		
Total cost per therm d.	2·24	2·25	2·21	1·55	1·76	1·70	1·85	1·75	1·79	2·50	2·20	2·44	2·27	3·61	3·47	3·56	3·46	1·86
Per therm, less credit for surplus steam, d.	**2·24**	**2·25**	**2·21**	**1·54**	**1·70**	**1·64**	**1·72**	**1·63**	**1·67**	**2·59**	**2·20**	**2·44**	**2·27**	**3·61**	**3·47**	**3·56**	**3·46**	**1·73**
Approximate thermal efficiency, p.ct.:																		
Without boiler	81·1	80·0	80·5	78·2	79·5	79·5	79·0	80·0	79·5	43·4	..	43·4	..	54·8	..	54·8	..	74·0
With boiler	82·6	82·6	82·9	80·5	81·5	81·5	82·4	83·3	83·0	..	62·8	..	51·3	..	62·3	..	58·3	78·0
Actual or estimated	Actual	Actual	Labour actual, gas and coal by addition	Actual	Actual	Labour actual, gas and coal by addition	Actual	Actual	Actual	Actual	Actual	Actual	Estimated	Actual	Estimated	Actual	Actual	Calculated from columns 8 and 11
Remarks	..	..	..	..	..	..	..	..	..	..	..	..	Waste heat boiler on 1 set only	..	Blow gas only through waste heat boiler	..	Oil on 1 set, waste heat boiler on other	74·7 p.ct. coal gas at 520 and 25·3 p.ct. blue water gas at 303
Column No.	1	2	3	4	5	6	7	8	9	10	10a	11	11a	12	12a	13	13a	14

* Corrected to 60° Fahr. and 30 in. (moist).

would have been the case with freshly wrought coal. As compared with Derbyshire coal full steaming was not possible—only 18 lbs. per sq. in., against 25 to 30 lbs.—and the throughput fell to 4·63 tons, a reduction of 14·2 p.ct. The gaseous yield was 69·6 therms per ton, and the output of the plant was thus 9017 therms per day, or 24 p.ct. less than when carbonizing Derbyshire coal. At the same time two additional men per 24 hours were needed, owing to the increased rodding, bringing the cost of labour per therm from 0·15d. to 0·23d. In spite of these factors, however, as the state of the coal market now renders it possible to buy Durham coal at 6s. 3d. per ton less than Derbyshire, the cost of production per therm with the former is considerably less than with Midland coal at the present time (Col. 4).

One half (5 beds) of the No. 1 Installation of vertical retorts erected in 1915 was later isolated, and tested for 10 days with screened Durham coal (Cols. 5 and 6). These retorts, due probably to their old design, give a still lower throughput (3·74 tons). They are worked without steaming, because, owing to the difficulty of obtaining high bottom temperatures, the introduction of steam appears to have no measurable effect on either the thermal yield or the composition of the gas. The yield of therms per ton is, however, practically equal to that obtained by steaming on the newer plant, and this is without doubt largely due to the screening.

The coal as elevated was found to correspond to the following grades:

	P.Ct.
Over 1 in.	38·7
½ in. to 1 in.	48·2
¼ in. to ½ in.	10·1
Below ¼ in.	3·0

The results of these tests are here tabulated.

Vertical Retorts on Durham Coal.

Installation and date of erection.	No. 3 Silica, 1926.		No. 1 Fireclay, 1915.
Number of retorts	28		20
Duration of test	8 Days		10 Days
Class of coal	Stock Durham.	Durham Guarantees.*	Screened Durham.
Conditions	Steaming	Steaming	Non-steaming
Coal carbonized, tons	1,037	..	747
Moisture in coal, p.ct.	4·8	..	3·5
Ash in coal, p.ct. wet basis	10·2	..	8·9
Throughput, tons per retort per day	4·63	4·70	3·74
Gas made, thousands c.ft.	15,105	..	10,340
Gas made, c.ft. per ton of coal	14,570	16,280	13,840
Calorific value, B.Th.U.	477·5	460	499·0
Therms per ton of coal	69·6	74·9	69·1
Dry ash-free fuel, tons	99·7	..	87·4
,, ,, ,, cwt. per ton of coal	1·92	2·65	2·34
Volatile matter in coke, p.ct. dry basis	2·2	2·0	2·9
Steam on retorts, lbs. per sq. in.	18	..	*Nil*
Combustion chamber temp. °C. top	1415	..	1254
,, ,, temp. °C. bottom	1190	..	935
Column number in Table II.	4	..	5

* Guarantees were based on dry coal containing 6 p.ct. of ash. Figures here given are corrected to raw coal.

Labour on Vertical Retorts.

The following table summarizes the labour employed under different conditions on the three vertical retort installations.

Labour Employed on Vertical Retorts per 24 Hours.

Installation	2	3	2 and 3	3	1	1
Number of beds	7	7	14	7	5	10
Coal and conditions	Derbyshire Steaming	Derbyshire Steaming	Derbyshire Steaming	Durham Steaming	Durham Non-Steaming	Durham Non-Steaming
Column in Table II.	1	2	3	4	5	6
Leading hand	1	1	1½	1	1	1
Elevator attendant	1	1	1	1	1	1
,, assistant	1	1	2	1	..	..
Coal wheelers	..	..	..	..	4	6
Topmen	3	3	6	6	3	6
Bottom men	3	3	4	3	6	12
Producer men	3*	3*	3	3		
Telpher driver	1	1	1½	1	1	1
Men required for scurfing and odd work	2	2	4*	1	1½	3
Men per 24 hours	15	15	23	17	17½	30

* Attend to waste-heat boilers.

Horizontal Retorts.

It is a matter for regret that, owing to the coal strike and other difficulties, it has been impossible to isolate under test conditions the reconstructed benches of horizontal retorts at Hilsea. These have therefore been omitted from the table of costs, and the figures for horizontal retorts have been calculated on the results of a series of tests on an older plant at the Flathouse works. This bench comprises 9 beds of nine, 24 in. by 16 in. D retorts, 20 ft. long, with a Fiddes-Aldridge simultaneous stoker; the coke dropping into telpher skips below the stage floor. It is equipped with a Spencer-Bonecourt "Kirke" waste-heat boiler, shown in fig. 6. Three tests were carried out—namely, two on unscreened Durham coal with 8 and 12-hour charges respectively, and one on Durham screenings, with 12-hour charges. The results of these tests are as follows:

Horizontal Retorts on Durham Coal.

Coal used	Unscreened 7	Unscreened 7	Screenings 12
Duration of test, days	8 hours	12 hours	12 hours
Duration of charge	668	567	985
Coal carbonized, tons	4·4	3·9	4·5
Moisture in coal, p.ct.	9·3	9·7	12·6
Ash in coal, p.ct. wet basis	8·1	10·3	10·4
Average weight of charge, cwt.	8,546	7,650	13,126
Gas made, thousands c.ft.	12,800	13,490	13,330
Gas made, c.ft. per ton of coal	523·5	520·0	515·8
Calorific value, B.Th.U.	67·0	70·2	68·8
Therms per ton of coal	98·3	96·1	175·8
Dry ash-free fuel, tons	2·9	3·4	3·6
,, ,, ,, cwt. per ton of coal*	1,322	1,333	1,312
Average combustion chamber temperature, °C.	7	8	9
Column No. in Table II.			

* Producers fed with cold coke, containing 8 p ct. of moisture.

Labour Employed on Horizontal Retorts, per 24 Hours.

	8-Hour Work.	12-Hour Work.
Leading hand	1	1
Machine men	3	3
Stokers and firemen	9	6
Coal and coke wheelers	8	7
Conveyor attendant	1	1
Telpher driver	1	1
Scurfer	1	1
	24	20

It cannot be said that these results represent the best horizontal retort practice, as the throughput of coal per retort per day is much lower than could be desired. The reason for this is found in the fact that the beds are of old design, and due in a year's time for resetting. The stoking machine, also, is the old type of "F.A." charger, and cannot be altered to give a heavy charge without considerable expense. It may be added that the coal carbonized in the newer horizontals at the Hilsea Works represents 30 cwt. per retort per day—a 50 p.ct. increase.

An interesting point (referred to above) is the fact that the screenings gave almost as high a thermal yield as the unscreened coal.

It should also be noted that in these tests the producers were fed with cold coke in order that all fuel might be weighed for the purpose of calculating the efficiency of the waste-heat boiler.

Blue and Carburetted Water Gas.

The columns referring to water gas (10 to 13a inclusive) are calculated in a similar manner, and on the same test results as in the 1922 figures, brought up to date, of course, in each case. The calorific value of the blue gas is taken as 303 B.Th.U. and the oil duty as 90 B.Th.U. per gallon—1·8 gallons of oil per 1000 c.ft. giving a finished gas of 465 B.Th.U., and about 63 c.ft. of additional gas per gallon of oil.

The costs are worked out with coke at 30s. per ton, and with oil at 5½d. per gallon. On this basis the cost of the therm in the form of water gas is considerably higher than any of the coal gas figures, but it must be remembered that the value set upon the coke used in water gas manufacture is really a hypothetical figure. As has been frequently pointed out, a reduction in the manufacture of water gas would result in the lowering of the market price of coke and consequent cheapening of the water gas therm. Figures are therefore given for the cost of gas per therm with coke at 26s. 6d. per ton,

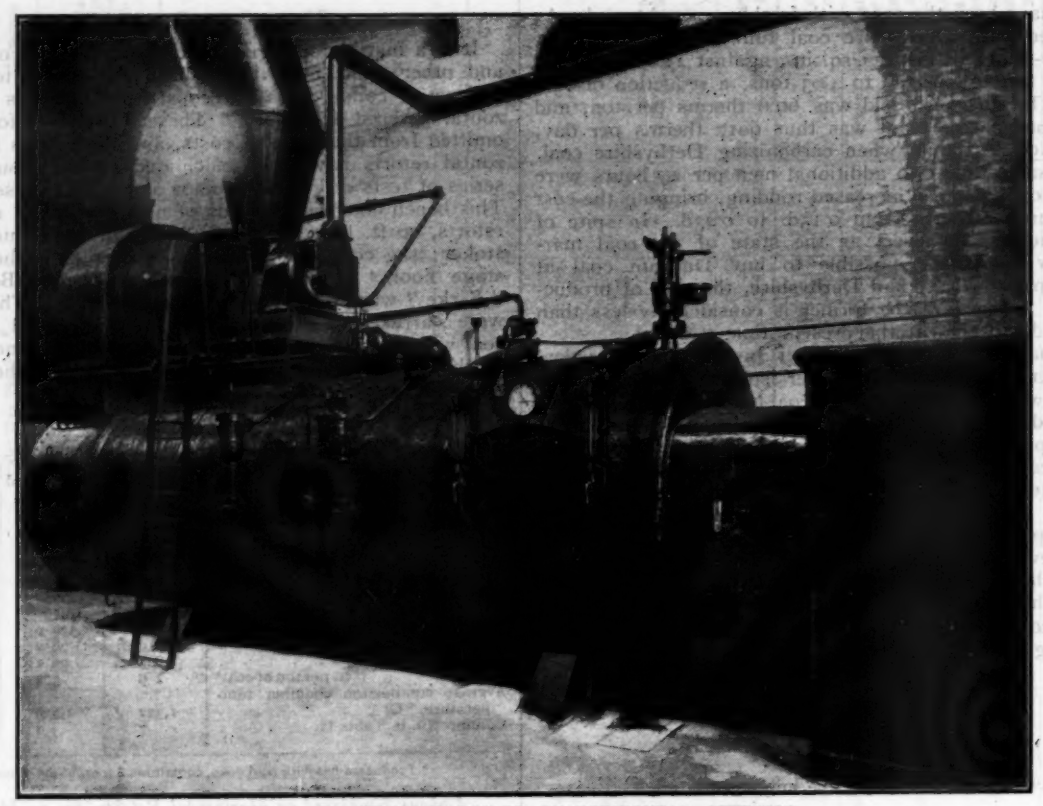

FIG. 6.—WASTE-HEAT BOILER ON HORIZONTAL SETTINGS.

this figure being the price of the lowest current coke contract.

THE VALUE OF STEAM PRODUCED.

In Cols. 10a, 11a, 12a, and 13a the water gas figures have been adjusted to allow for the operation of the waste-heat boiler *on one set*. To give an accurate comparison, the steam produced from the "Kirke" waste-heat boiler in the horizontal house should also be credited to the cost of production, since it is available for use in the power house and other sections of the works, whereas that produced from the vertical retorts waste-heat boilers is mostly absorbed on the plant itself when working under steaming conditions. As previously explained, therefore, credit has been allowed in the last figures given in each portion of the table for surplus steam produced; such credit including cost of both breeze and labour entailed in generating an equal quantity of steam in Lancashire boilers.

COMPARISON OF COST FIGURES.

It is felt that the figures given in Table II. are self-explanatory; the main point to be noted being that the cost of the therm is *very largely a question of the cost of coal into store*. This being the case, Durham coal gives unquestionably the cheapest therm when carbonized in the newest type of vertical plant. The next process in order of cost is the straight carbonization of Durham coal in unsteamed verticals and in horizontals; the steaming of Derbyshire coal in vertical retorts being still dearer, followed by blue water gas and carburetted water gas —the most expensive of all. The high cost of water gas makes the production of a mixed gas of 465 B.Th.U. consisting of 74·7 p.ct. of coal gas and 25·3 p.ct. of blue gas (Col. 14) a more expensive matter than the manufacture of straight coal gas, but it is at the same time appreciably cheaper than gas of the same quality made from Derbyshire coal in steamed vertical retorts.

The price of coke also has a very important bearing on the cost of the therm. Taking all other costs as constant, an interesting set of curves may be constructed for the various installations with the cost of gas per therm plotted against the price of coke per ton. An example of such a graph illustrating Table II. is given in fig. 7. It will be seen from this that when the price of coke falls to 25s. 2d. the cost of blue water gas per therm becomes equal to the cost of gas produced from Derbyshire coal in the new vertical installation. Similarly, the price of 22s. 1d. would give an equal cost per therm in the case of blue water gas (Col. 11) and gas from horizontal retorts on 12-hour work (Col. 8).

WASTE-HEAT BOILERS.

Boilers are in operation on the main flues of all the carbonizing plants above referred to, and there is also

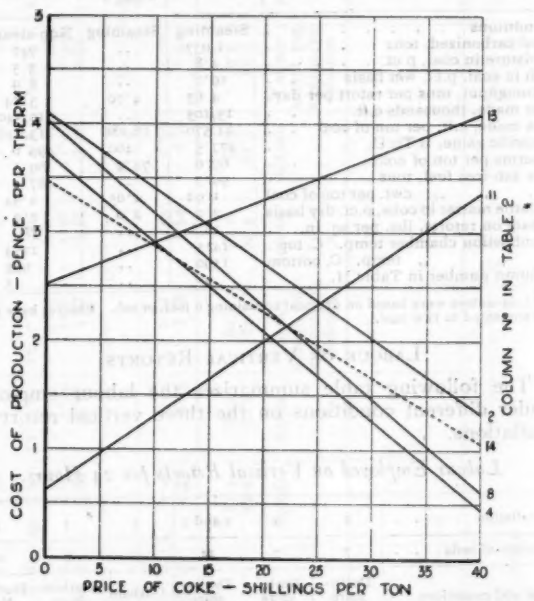

FIG. 7.—EFFECT OF VARYING COKE PRICE ON COST OF GAS.

Variation of Cost of Therm with Price of Coke.

Curve No.	—	Column No. in Table 2.
2	No. 3 Vertical Retort Installation, Derbyshire Coal, steaming	2
4	No. 3 Vertical Retort Installation, Durham Coal, steaming	4
8	Horizontal Retorts on Unscreened Durham Coal, 12-hour work	8
11	Water Gas Plant, Two Sets on Blue Gas	11
13	Water Gas Plant, Two Sets on Carburetted Water Gas at 465 B.Th.U.	13
14	Mixture of "8" and "11" at 465 B.Th.U.	14

a waste-heat boiler in the water gas house of sufficient capacity to take both make and "blow" gases from one set, when making blue gas. It is the practice, when making carburetted gas, to gasify the whole of the oil on one set, working the second set blue in order to obtain the maximum duty from the boiler. The waste-heat boiler in the horizontal house is equipped with an electrically driven fan, while the fans in the vertical houses are in each case driven by high-speed steam engine and chain drive.

Each of these boilers has been tested in conjunction with its respective gas-making plant, and the table at foot gives the principal results. In view of the exhaustive trials and reports made by the Institution's Research Committees and others on the subject, the author does not feel it necessary to give these tests in greater detail.

Thermal Efficiency of Manufacture.

The approximate thermal efficiency, with and without waste-heat boiler, for each process, has been added to Table II. These figures require little comment, but the author would emphasize two points. First, the highest thermal efficiency does not necessarily imply the highest yield of gaseous therms per ton; and, secondly, the most efficient process, thermally, is not always that which offers the most economical commercial result.

Thermal efficiency alone, therefore, is not a sufficient index to the gas engineer of the relative values of particular plant or processes. His aim should be to produce from the raw material at his disposal the maximum number of gaseous therms at the lowest possible cost.

Efficiency of the Steaming Process.

While dealing with carbonization in continuous vertical retorts, attention may again be called to this subject; and a suggestion may be made that an endeavour to utilize a larger proportion of the steam introduced into the retort would prove a very useful field for investigation by research workers, as well as by manufacturers of the plant.

This efficiency can, in works practice, only be calculated approximately from the gas analysis; but it is of the order of 30 p.ct. It is somewhat surprising that when steam is admitted at the base of a retort at the rate of (say) 100 lbs. per hour, 70 p.ct. of it should escape unchanged at the top.

The cost of this steam is perhaps negligible where waste-heat boilers are in use, but the author would suggest that the matter is of considerable importance from the point of view of condensation and ammonia recovery. At the Hilsea Works the virgin liquor amounts to no less than 50 gallons per ton of coal, at a correspondingly low ounce strength. The result is a bigger load, both in throughput and cost, on the manufacture of sulphate, and has in fact prevented the adoption of acid washers, which were desired as a relief to the sulphate plant.

Refractory Materials.

Attention has been drawn in the reports of the Gas Investigation Committee to thermal losses in carbonizing plants due to radiation, to the sensible heat of the waste gases, and to air infiltration into flues of settings; and steps have been taken to increase the economy of working by the use of non-conducting materials, waste-heat boilers, and more efficient control. Combustion chamber temperatures have been increased to over 1400° C., giving a greater throughput per retort and a larger number of therms per ton of coal carbonized. The use, therefore, of silica materials is almost essential. The Refractory Materials Research Committee of the Institution has accomplished much in advancing the general standard, and makers of all classes of refractory materials have met the demand for higher quality in a very satisfactory manner; but there is still room for improvement, especially with regard to the construction of the silica portions of the plant, in allowing for the correct expansion.

The refractory materials used in No. 2 and No. 3 vertical retort installations are shown in fig. 8. From this it will be observed that in the No. 2 Installation, erected in 1920 and put to work in 1921, the material used consisted of Glenboig first-quality fireclay bricks throughout, except in the upper portion of the back walls in the combustion chambers, which were constructed in Meltham silica.

Samples of the whole of the bricks were carefully tested before use, and satisfied the Institution's Standard Specification for Refractory Materials.

The installation was put to work, cooled-down, and one setting dismantled for inspection and pointing in April of this year; and the following is a brief report as to the condition of the refractories:—

The retorts are in very good order after gas-making for 2190 days, during which period 8650 tons per retort of Derbyshire washed nuts and screened coals have been carbonized at an average combustion chamber temperature of 1300° C., and using steam at a pressure of 15 to 30 lbs. per sq. in. for steaming the charge.

Some disintegration and erosion, however, have taken place in the top course of firebrick—the course immediately under the cast-iron mouthpiece (see fig. 9, p. 855). For some two years much "podging" has been necessary at this level after each scurfing period, and the disintegration is largely due to the variations in temperature which occur in the material between ordinary working and scurfing periods. Down to the level of the gas and air nostrils the surface of the bricks is in good condition, and the joints are firm (fig. 9, p. 855); but below this level for a depth of 5 or 6 ft. the faces of the panelled bricks are concave and badly cracked, pitted, and distorted (figs. 10, 11, and 12, pp. 855-6). The remaining portions of the retorts are good, and the appearance of the surfaces is little changed, with the exception of a little erosion round the steam nostrils. Beneath this level the bottom blocks show worn and grooved surfaces on the extractor side of the retort only (fig. 13, p. 856), probably due to the abrasive action of the descending coke and to bottom rodding of the charge. In the combustion chambers little or no fusion is noticeable.

Considering the throughput and the general methods of working, the behaviour of the firebrick retorts has been abnormally good, and it is estimated that each retort, after being reset for a depth of 10 ft. from the top, will carbonize a further 9300 tons of coal under the same conditions of temperature and throughput, before a complete reconstruction is necessary.

The refractory materials used in the construction of No. 3 Installation, which was put into operation in September, 1925, are also shown in fig. 8, which clearly in-

Performance of Waste-Heat Boilers.

Coal Gas Plant.					Water Gas Plant.	
—	No. 1 Vertical Retorts.	No. 2 Vertical Retorts.	No. 3 Vertical Retorts	Horizontal Retorts.	One Set Making Blue Gas.	
Coal carbonized, tons	789	756	2,250	2,219		
Water evaporated, lbs.	438,200	377,900	1,719,140	1,203,300	Dry coke to generator, lbs. per hour	1552
Lbs. steam per ton coal	555	500	764	993	Ash in coke, dry basis, p.ct.	13·7
Lbs. steam per lb. dry carbon burnt as fuel	2·35	2·14	3·71	2·98	Water evaporated from and at 212° Fahr., lbs. per hour	3550
Pressure of steam, lbs. per sq. in.	95	100	101	99	Lbs. steam per lb. dry coke.	2·29
Temp. of superheated steam, ° Fahr.	592	..	730	Saturated	,, ,, ,, carbon	2·66
Waste gas temp. inlet, ° Fahr.	770	..	1,494	850	,, ,, ,, 1000 c.ft. gas	88·5
,, ,, ,, outlet, ° Fahr.	457	..	520	379	Steam pressure, lbs. per sq. in.	120
Feed water temp., ° Fahr.	201	..	198	71		Saturated
Efficiency of boiler, p.ct.*	88·3	..	88·2	90·0		
Fan consumption, lbs. per ton	80	..	60	10 KW.		
Net output of steam, lbs. per ton of coal	475	..	704	850		
Column No. in Table II.	5 & 6	1	2	7, 8, 9	Column No. in Table II.	10a

* Total heat of steam from feed temperature / Heat absorbed from waste gases

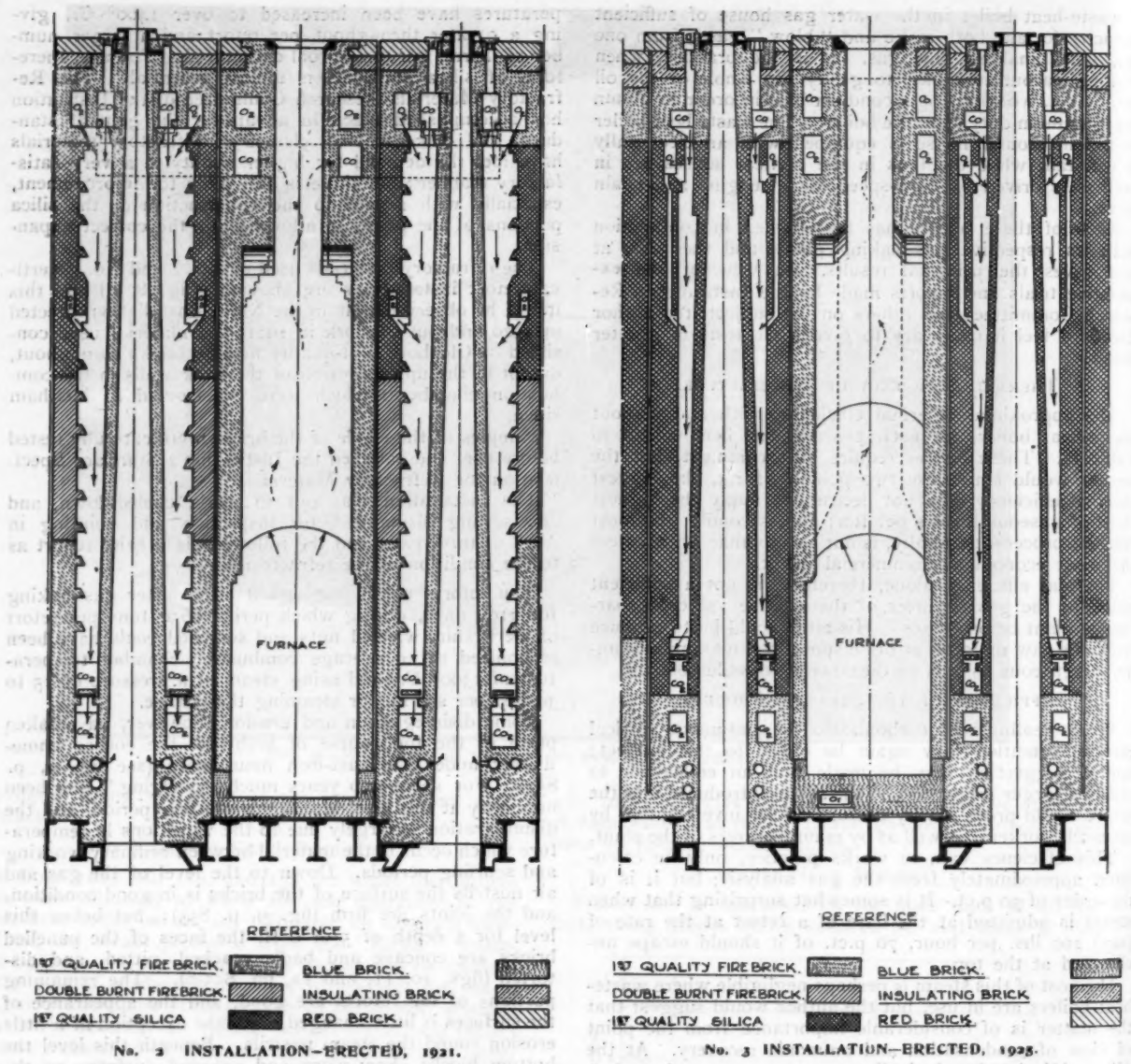

FIG. 8.—REFRACTORIES USED IN VERTICAL RETORTS.

dicates where the different grades are used in the various parts of the setting. Glenboig fireclay bricks were used only in the upper portion of the retort above the silica; the rest of the fireclay material being supplied by the Stourbridge Refractories Company. The silica for the retorts, and for the back walls of the combustion chambers for a depth of approximately 17 ft. below the level of the nostrils, was supplied by the Meltham Silica Company.

By the use of silica instead of fireclay in the construction of these modern settings a considerable saving in materials can be effected by reducing the centres of the beds from 15 ft. 6 in. to 13 ft. 9 in. Here, however, no advantage was taken in this respect, as it was desired to keep the third installation uniform with the second. This explains the reason for building a 1 ft. 9 in. straight wall between each setting.

As in the case of the firebrick materials, samples of the bricks were carefully tested before use, and had to conform to the Institution's Standard Specification—namely:

Silica material	Fusion point not less than Seger Cone 31 (equivalent to 1690° C., or 3074° Fahr.). After expansion or contraction not more than 0·5 p.ct.
First-quality firebrick material .	Fusion point not less than Seger Cone 30 (equivalent to 1670° C., or 3038° Fahr.) After expansion or contraction not more than 0·75 p.ct.
Second-quality firebrick material	Fusion point not less than Seger Cone 26 (equivalent to 1580° C., or 2876° Fahr.) After expansion or contraction not more than 1·15 p.ct.

Apart from leakages of combustion and inert gases into the retort, and of coal gas at times into the waste gas flues through the cavities allowed during erection for expansion of the silica, the behaviour of the refractories has so far been good; and it is hoped they will have a considerable life. These cavities should theoretically have closed, but they did not do so owing to the total reversible and permanent after-expansion of the silica being less than was anticipated; and it is suggested as a reason that an improved quality of material was delivered, the permanent expansion of which in actual practice was considerably lower than the amount allowed for in the building of the retorts. The leakages, however, make the regulation and control of the settings difficult; and if the greatest care is not exercised, high temperatures are easily, and at very short notice, attained in the horizontal waste gas collecting flues, and in the uptake flues of the settings.

Fusion has already taken place; one waste gas vertical uptake flue being completely blocked. To safeguard against further damage in this direction, the heating arrangements of the settings have been modified by working with an excess of secondary air in all combustion chambers, and with certain waste gas check tiles closed. These retorts have not been sufficiently long in use and under observation to allow the author to give any useful information concerning their probable working life. The only

FIG. 9.—TOP COURSES OF RETORT WALL.

wear and tear noticeable so far, after 18 months' working, is at a depth of about 5 to 6 ft. from the top of the setting, where on both sides of the retort face the surfaces of the bricks for about two courses in depth are slightly

FIG. 10.—INSIDE OF RETORT WALL IMMEDIATELY UNDER NOSTRIL LEVEL.

worn, due to the abrasive and scraping action of the poking rods, or possibly to disintegration caused by change of temperature between ordinary working and scurfing periods. The combustion chamber temperatures range from 1350° C. (top) to 1150° C. (bottom), and the throughput is 5·4 tons of Derbyshire coal per day—an increase over the fireclay retorts of 30 p.ct.

Each combustion chamber in both No. 2 and No. 3 Installations is provided with an auxiliary secondary air inlet, in order to assist steaming by extending the zone of maximum temperature towards the bottom of the retorts. In the No. 2 Installation this two-stage heating has not yet been used, and in No. 3 it was discontinued after a very short period.

For vertical retort installations, the life of silica under varying working conditions is not yet established. To those faced with the immediate necessity of reconstructing plant, it is difficult to say if the adoption of silica refractories will prove to be the most efficient and economical. In general the improvement in quality has been very marked, but a fair amount of trouble is still being experienced (as explained above) in making due allowance for the peculiar expansion which takes place in silica construction on heating. It is hoped, however, with more experience this difficulty will disappear.

MAINTENANCE.

There was at one period some misgiving as to what would be the cost of repairs and maintenance in continuous vertical retorts; but much experience is now available from actual practice, which declares that, with well designed and constructed settings, properly worked and supervised, the costs are extremely reasonable.

The No. 2 Installation (Glenboig retorts) has been working continuously, and 8650 tons of coal have been carbonized per retort. It is now necessary to rebuild the top 10 ft. of the retorts and the combustion chambers, and, for the second time, to reline the producers. The regenerators do not need repairs. When this work is completed the total amount spent on maintenance of the settings and ironwork will be £6700, which represents 6·64d. per ton of coal or 0·08d. per therm.

A further duty of 9300 tons may be then anticipated; but at the end of that period (namely, after 12 years' work) a more costly renewal will have to be faced in the rebuilding of the whole of the retorts, combustion chambers, back-walls, and the flues in that part of the setting. Taking the maintenance of setting ironwork, fittings, &c., to be the same during each 6-year period, the final charge will be £18,250, or 9·04d. per ton, and 0·11d. per therm; and this figure should be taken as the actual maintenance cost, leaving a practically new plant after the second repair.

FIG. 11.—OUTSIDE OF RETORT WALL, IMMEDIATELY UNDER NOSTRIL LEVEL.

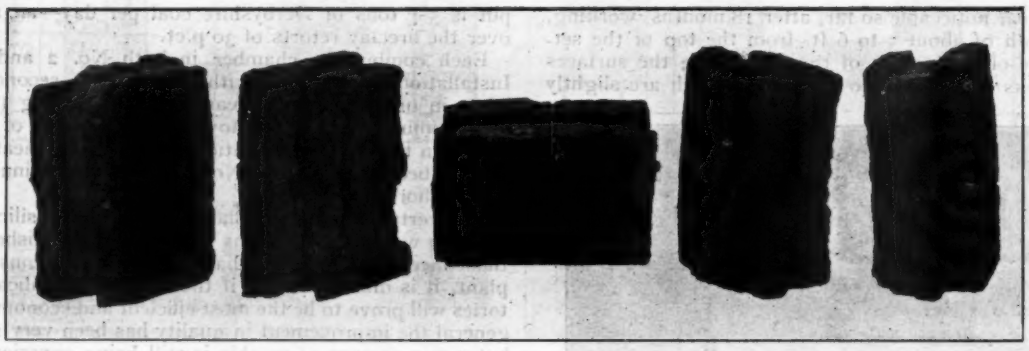

FIG. 12.—PANELLED BRICKS TAKEN FROM RETORT WALLS (TOP COMBUSTION CHAMBER).

FIG. 13.—BOTTOM COURSES OF RETORT BLOCKS.

With regard to the silica installation (No. 3), maintenance can only be estimated at present. In the author's opinion these retorts may be expected to carbonize 10,000 tons of coal before the first reset. Allowing for both the higher cost of silica renewals and the increased throughput, the cost of maintenance at the time of the first repair will be practically the same as in the former case—namely, 6·6d. per ton, or 0·08d. per therm. The complete reset in silica is, however, a more expensive matter, and it is estimated that the maintenance over 20,000 tons per

retort will accordingly be 9·6d. per ton, or 0·12d. per therm.

The top and bottom mountings and ironwork of the retorts in No. 2 Installation, including coke extractor castings, have also been in continuous operation, and have been kept in good working order at a very low cost.

The following is a list of the castings replaced and of repairs to others carried out, the cost of which is included in the maintenance figures given above:

Top mouthpiece castings (fig. 14).
Skew castings forming top of coke chamber (fig. 15).
Sloping ends of coke chamber (fig. 16).
" Half-round " plate in bottom coke valve (fig. 17).
Shafts to bottom coke valve (fig. 17).

It may be added that the maintenance of coal handling plant on the vertical installation, including rotary wagon tipper, crusher, and gravity bucket conveyor, amounts

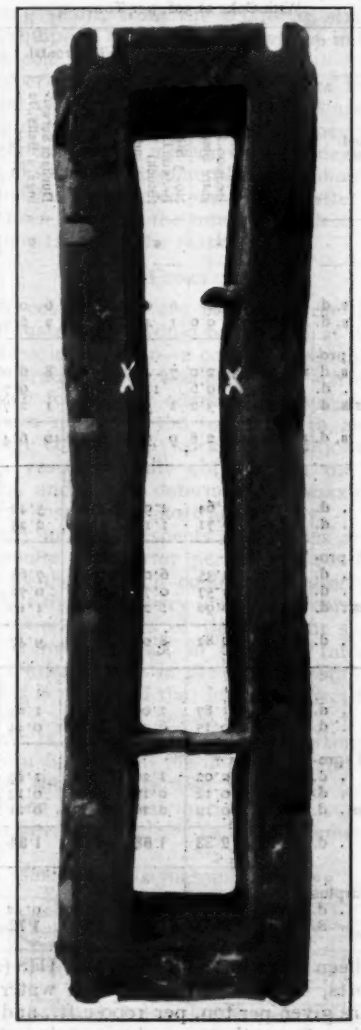

FIG. 14.—TOP MOUTHPIECE CASTING.
(Replaced.)

to 0·70d. per ton of coal carbonized, and on the telpher coke handling plant 0·59d. per ton of coal, or 0·72d. per ton of coke and ash handled.

In the case of the horizontal retorts, considered in connection with comparative tests and costs (Table II.), the actual maintenance over a long period works out at something over 1s. per ton. It is recognized, however, that the use of this figure would scarcely give a fair comparison, since for reasons already explained the throughput of coal is very low. The cost has therefore been corrected to a basis of 30 cwt. per retort per day, with a result of 9¾d. per ton, or 0·14d. per therm.

The maintenance of two sets of water gas plant, including turbo-blowers, has been recorded on exactly similar lines, and amounts to 0·14d. per 1000 c.ft. This gives

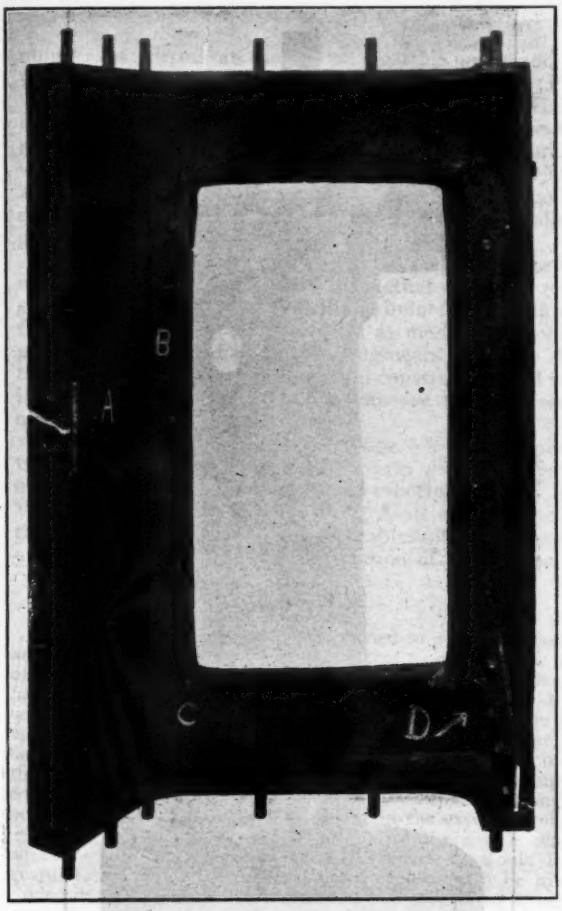

FIG. 15.—TOP OF COKE CHAMBER.
(Repaired.)

for blue water gas 0·05d. per therm, and for carburetted water gas at 465 B.Th.U., 0·03d. per therm.

Capital Costs.

It is very difficult to lay down definite figures regarding capital cost of carbonizing installations, as the circumstances and conditions of construction vary so much in different localities.

FIG. 16.—END PLATE OF COKE CHAMBER.
(Replaced.)

FIG. 17.—BOTTOM COKE VALVE.

(Curved plate and shaft replaced.)

The cost of the No. 3 Installation (silica), described in the early part of this paper, was as follows:

(1) Foundations, retort house, bench of 7 settings, and fittings, overhead coal and coke bunkers—48 hours' capacity	£41,000
(2) Coal handling plant, comprising coal breaker, 50-tons per hour gravity bucket elevator and conveyor, 75-tons per hour cross band conveyor, motors and starters, and part cost of telpher coke conveying plant	£4,707
(3) Waste-heat boiler	£2,290
Total cost of installation	£47,997

Taking the figures in Col. 2 of Table II.—namely, coal carbonized 151·6 tons, gas made 2,564,000 c.ft., and therms produced per day 11,860—the capital cost works out as under:

Cost per ton of coal carbonized per day	£317
Cost per million c.ft. of gas made per day	£18,720
Cost per 1000 therms produced per day	£4,047

During the past few years, however, the manufacturers of verticals have devoted themselves very closely, and with considerable success, to the question of reducing the capital cost per ton of coal carbonized and per therm of gas produced, with the result that to-day, for the larger installations, the difference in capital cost of horizontals and verticals is very little, and compared on the basis of output of therms per day the balance is, if anything, in favour of the latter. This result, as far as the Woodall-Duckham plant is concerned, has been brought about by building the retorts entirely of silica, modifying the settings so that the retorts are built in a unit block, without regenerators but complete with waste-heat boilers, and by building the producers in a battery placed on the ground. A new vertical retort installation, designed on these modern lines, of 28 retorts, capacity 12,000 therms per day, complete with retort house and conveying plant, erected at Portsmouth, and giving the results shown in Table II., Col. 2, would now cost approximately £290 per ton of coal carbonized per day, or £3625 per 1000 therms.

The capital cost of a new horizontal retort installation of 2-million c.ft. capacity, complete with house, stoking machine, conveying plant inside the house, and waste-heat boiler, works out at approximately £4000 per 1000 therms; while the latest type of water gas plant, including 2 million c.ft. set, blowing plant, coke handling plant, house, waste-heat boiler, &c., costs about £26,000, or £2796 per 1000 therms of carburetted gas at 465 B.Th.U. (£4290 per 1000 therms of blue gas).

FINAL COMPARATIVE COSTS.

To obtain a final comparison of the relative over-all therm costs, maintenance and capital charges may be added to the cost of production (net materials, *plus* labour—Table II.).

TABLE III.—*Final Comparative Costs.*

With Coke at 30s. per Ton.

Plant.	Vertical.			Horizontal.		Water Gas.	
Installation, Coal and Conditions.	No. 2 Fireclay, 7 Beds on Derbyshire Steaming.	No. 3 Silica, 7 Beds on Derbyshire Steaming.	No. 3 Silica, 7 Beds on Durham (Stock) Steaming.	Durham screened, 9 Beds, 12 Hours.	Durham Screenings, 9 Beds, 12 Hours.	1 Set on Blue Gas.	1 Set on Carburetted Gas at 465 B.Th.U.
Col. No. in Table	1	2	4	8	9	10	12
Per ton—							
Net coal s. d.	12 2	12 2	6 0	6 0	6 0	..	..
Labour s. d.	1 3·9	1 0·0	1 4·2	2 6·4	2 6·0	..	..
Total cost of production s. d.	13 5·9	13 2·0	7 4·2	8 6·4	8 6·0	..	..
Maintenance d.	9·0	9·6	11·2	9·7	9·7	..	..
Capital charges s. d.	1 3·2	1 3·2	1 5·7	1 2·7	1 2·7	..	..
Total s. d.	15 6·1	15 2·8	9 9·1	10 6·8	10 6·4	..	..
Per 1000 c.ft.—							
Net materials d.	8·44	8·64	4·94	5·34	5·40	7·17	16·19
Labour d.	0·92	0·71	1·11	2·25	2·25	1·40	1·24
Total cost of production d.	9·36	9·35	6·05	7·59	7·65	8·57	17·43
Maintenance d.	0·52	0·57	0·77	0·73	0·72	0·14	0·14
Capital charges d.	0·88	0·90	1·22	1·09	1·10	0·68	0·68
Total d.	10·76	10·82	8·04	9·41	9·47	9·39	18·25
Per therm—							
Net materials d.	1·82	1·87	1·03	1·03	1·05	2·37	3·48
Labour d.	0·20	0·15	0·23	0·43	0·44	0·46	0·27
Total cost of production d.	2·02	2·02	1·26	1·46	1·49	2·83	3·75
Maintenance d.	0·11	0·12	0·16	0·14	0·14	0·05	0·03
Capital charges d.	0·19	0·19	0·26	0·21	0·21	0·22	0·15
Total d.	2·32	2·33	1·68	1·81	1·84	3·10	3·93
Credit for surplus steam d.	*Nil*	*Nil*	0·01	0·12	0·12	0·39	0·13
Net total cost d.	2·32	2·33	1·67	1·69	1·72	2·71	3·80

This has been done in the Table, No. III. (above), for vertical retorts, horizontal retorts, and water gas; and the results are given per ton, per 1000 c.ft., and per therm. The net total costs per therm so obtained do not materially affect the general conclusions arrived at in considering Table II., and, when taken in its relation to labour, maintenance, and capital costs, the net cost of coal still stands out as the predominant factor.

EXTENSIONS.

Each carbonizing system has its own peculiar advantages and disadvantages, and local circumstances and markets vary so greatly that the particular processes and grade of gas most suitable for one undertaking might be very different from those which would rightly be chosen in other circumstances.

It will therefore always rest with engineers to decide for themselves which processes and grades of gas best meet the requirements of their respective districts. At the present time, if it is necessary to make extensions to the carbonizing plant, the engineer must consider the question from many points of view; and it is often most

difficult for him to decide, even in the case of a works under his control, which system (verticals and steaming, or an installation of horizontals or chamber ovens with or without blue water gas) will produce gas at the lowest cost per therm. He has to consider *inter alia*, the following :

(1) The class of suitable coal which owing to local circumstances is most easily and cheaply obtained.
(2) Fuel and residuals.
(3) Ground space.
(4) Labour costs.
(5) Repairs and renewals.
(6) Capital.

Another factor which must not be overlooked is the capacity and condition of the distribution plant.

The one aim, of course, is to adopt such methods in the process of manufacture as will place at the disposal of the consumers a cheap gas which will give the best results under modern requirements. The most desirable carbonizing plant, from the economic standpoint, is the one best equipped to meet the variations in the commercial values of coal and residual products.

The experience of the past few years has proved that cheap coal and low receipts for residuals are not usually of such long duration as to encourage engineers to bind themselves definitely to one method of carbonization; and therefore it is desirable that some flexibility should be provided. Plant must be constructed and erected after due consideration has been given to the trend of modern invention, and a long view taken of the markets.

Conclusion.

All the costs given are estimated on the assumption that each installation would be worked at its full capacity for 365 days in the year—a condition which rarely obtains in actual practice, but which places each of the systems on an equal footing for comparative purposes.

The main object of the tests was to ascertain, under the average commercial working conditions as ordinarily practised, results usually obtained on the particular installations, and not to determine the maximum efficiency and lowest cost over a short period only.

Naturally in some respects the figures are not so good as the results of shorter period test conditions, nor so accurate as those which could be secured at a research station; but they offer very interesting comparisons of the carbonizing possibilities of the different systems.

There is no reference in the cost tables to freshly-wrought Durham coals in the No. 3 Installation of verticals; and it is regretted that in this respect the figures are incomplete.

The results obtained in the carbonizing departments have a vital bearing on the declared standard of calorific value; and the latter is also influenced by the capacity and condition of the distribution system. The final aim, in fact, is always to deliver to the consumer the requisite number of therms at the lowest possible price and at a uniformly satisfactory pressure. In the case of Portsmouth, the value declared in 1921 was 450 B.Th.U.; and in the light of subsequent experience and experiments no reason has been found for deviating from this figure. It will be agreed, on perusal of the charts illustrated in fig. 18 (North and South limits of the district), that no difficulty is encountered in the distribution of this quality of gas.

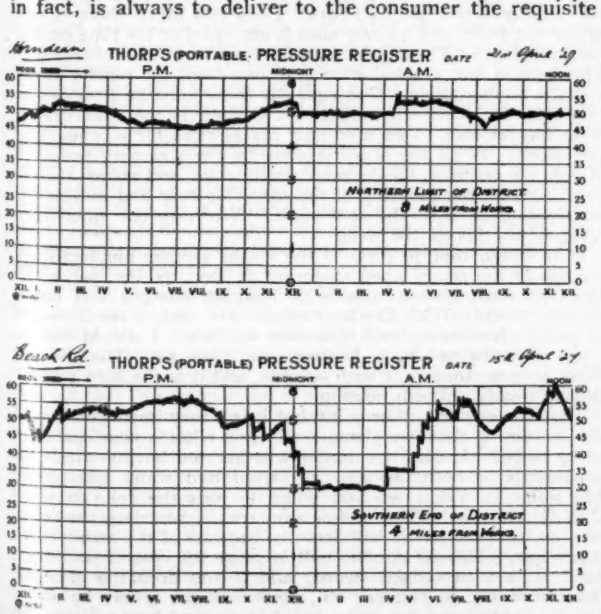

FIG. 18.—PRESSURE CHARTS FROM NORTHERN AND SOUTHERN LIMITS OF DISTRICT.

The author has only dealt with his own processes and methods, and he hopes that the actual working results given will be of some value to the industry in indicating the position in what can be taken as modern carbonizing practice; and to individual gas engineers as to the direction which their own experiments in construction and working might well take in order to improve the processes in question.

The author wishes to acknowledge his indebtedness to the members of his staff for the help given in carrying out the tests and experiments, and especially to Mr. S. E. Whitehead, B.Sc.Eng. (Member), Assistant Engineer of the Company, for compiling the tables of costs, and for assistance rendered in the preparation of this paper.

Discussion.

The PRESIDENT: We have just listened to a most interesting and highly valuable paper; and it seems to me that the more often we read the paper, the more valuable will it become. At first glance, Mr. Carmichael would appear to have provided us with plenty of powder and shot, so that we might riddle him; but I think you will find, on a closer perusal of the paper, that he has, true to the traditions of his race, very adroitly hidden the greater part of the target at which we have got to aim. I trust, however, that some of you will succeed in finding the bull's eye. I congratulate the author on the excellent manner in which he has prepared his paper and the simple way in which he has set out the tables, and particularly would I congratulate him on the excellent photographs which he has included in the paper. We have recently been listening to certain remarks of Sir Arthur Duckham with regard to museums. These photographs are highly interesting; and it does seem to me that there is a good deal in Sir Arthur's suggestion that if we had a museum or collection of photographs—similar to those in this paper—it would be highly interesting and most valuable to all of us when studying the question of refractory materials. The paper is now open for discussion.

Mr. FRANK PRENTICE (Ipswich): The paper we have just listened to is of intense interest, and I certainly compliment the author on the way in which he has dealt with an intricate though interesting subject. There is just one part of it to which I should like to refer. It was thirteen years ago that we put up our first verticals at Ipswich, and we travelled much the same road as apparently the author has done. We rapidly discovered that unscreened Durham coal, for which our plant was laid out, created no end of difficulties in the vertical retorts, and we therefore adopted a somewhat similar method to that of the author—though perhaps it was not done so effectively—of taking out the extremely fine portions of the coal and leaving the larger portions to go through the verticals. This we did by raising ploughs on flat steel conveyors about 1½ in., which allowed a certain portion of the fine coal to go forward to the horizontals; and the remainder we used satisfactorily in the verticals.

During the strike, however, we had an extraordinary experience; at least it seemed so to me at the time. We were inflicted with the most awful coal from the Continent that it has ever been my lot to see; and when I saw some of these cargoes of coal coming in with so much small in them, I trembled to think what the result would be when the coal was put into the verticals. To my amazement very little trouble occurred. The coal went through, not with very good results, but without serious trouble. The coal did not swell; and this at once put me on to a line of thought. Is not the trouble due entirely to the fact that the coal swells? I have since found that by adding a very small proportion—say, 3 or 4 p.ct.—of non-swelling coal, you can work verticals with a swelling Durham coal practically without trouble. When you use unscreened Durham coal—and use it all—what happens in my judgment is this: You fill the retort practically full, and if you have taken out the smalls, you have left interstices which take up the swelling. Of course, you can, by adding something—preferably a small proportion of non-swelling coal—to the Durham coal, counteract the swelling, and the trouble vanishes. In this case it is not necessary to remove the fines. That is our experience; and I give it you for what it is worth.

Recently, one of the large Durham collieries has adopted a method of treating its coal whereby the extremely fine dust is taken out. You cannot call it screened coal, but the real dust is removed; and I can assure you the result is amazing. I do not know whether my friend Sir Arthur Duckham is here. If he is, I am sure he will be pleased to hear me, because he

has had some abusive letters from me at times about the verticals. However, it is due to him for me to say that, with his latest setting and with the coal from which the dust has been taken, I have no trouble whatever, and I can use the coal just as it comes in. It occurred to me that this experience might be interesting to some of you who are situated as I am, and have similar troubles.

Mr. W. H. WARREN (Gas Light and Coke Company): I should like to add my thanks to Mr. Carmichael for his very interesting paper. He has set out in a most comprehensive and able manner the results of the gas-making plant at his disposal. He has given us his costs, and has left us to draw our own conclusions. These conclusions, however, I find most startling. From my point of view, the most interesting comparison in the paper is that between his horizontal and his vertical plant. On the one hand we have a plant which is the last word in carbonizing practice—I refer to the vertical plant, which is new and up to date—and on the other hand we have a comparatively old installation. I will not say it is obsolete, but it is certainly not up to date. The horizontal plant is uneconomical as regards size, as regards the machine which it employs, and in the design of its settings. It has a truly awful fuel figure—viz., 3·4 cwt. of dry ash-free coke per ton of coal carbonized—and it is being asked to make a gas of an uneconomical quality for horizontal retorts. It is due to be re-set next year. In spite of all these disabilities, we find that the commercial efficiency is almost equal to that of the vertical plant, and that the thermal efficiency is actually superior. In addition to this, the author has been able to use screenings on the horizontal plant, and so materially assist the carbonization in the vertical plant. In that connection I should like to ask the author how he manages to make the proportions of through coal and screenings fit the respective requirements of the two plants in use.

The author also states that carbonizing the screened coal in the verticals offers a further advantage in that he is able to sell a coke which has a lower percentage of ash, and to use the remainder of the coke, with a high percentage of ash, in his water gas plant. This is all very well from one point of view, but it occurs to me that the cost of water gas may be increased for that reason. Or is it that the author has discovered that vertical coke, especially a coke from steamed verticals, is relatively unsuitable for use in water gas plants? The horizontals are mentioned as having a fuel consumption on test of 3·4 cwt. per ton of dry ash-free coke; and the verticals, unsteamed, have a fuel consumption of 2·34 cwt. per ton of dry ash-free coke. Both these installations apparently make 11 cwt. of coke and breeze for sale; and I assume the same coal is used. What has happened to the rest of the coke which the verticals make?

Mr. C. VALON BENNETT (Rochester): I should like in the first place to add my thanks to the author for this paper. As one who is responsible for using both continuous vertical and also horizontal retorts, as well as operating carburetted water gas plant, the paper is of special interest to me. Though at first sight it might appear that there are many questions we should like to ask, the paper has been so well written that when we look into it more carefully we find that nearly every question is answered for us. I am particularly interested in the removal of the fines from Durham coal for continuous verticals; and I should like to ask the author what is the size of the mesh of the bar screens he has, and also whether, after all the coal has passed over the screens, it is subsequently crushed. I think the author is right in stressing the quality of the coke produced, because I do feel, as one who produces both classes of coke—horizontal and continuous vertical—that the more attention we give to the production and preparation of coke suitable for domestic uses, so much the better for the industry in general.

As to the author's remarks with regard to scurfing retorts, I should be glad if he will tell me whether the coal hoppers in his plant are so constructed that coke may be fed to some of the retorts, and, at the same time, coal to the others, and, if these hoppers have been so altered, whether the results he has obtained are sufficient to justify the expenditure involved in that alteration.

I think the author is to be congratulated on the reduction of his labour costs. I should like to read something which the author says in his paper, because I think it is of very great importance. It appears under the heading of "Thermal Efficiency of Manufacture": "First, the highest thermal efficiency does not necessarily imply the highest yield of gaseous therms per ton; and secondly, the most efficient process, thermally, is not always that which offers the most economical commercial result." I think this is one of the most important points in the paper; and when we read the paper through again after we get home, I think this is one of the important things to bear in mind. I should like to ask the author if the increase in the throughput of Derbyshire coal (5·4 tons per day—an increase over the fireclay retorts of 30 p.ct.) is due not only to an increase of temperature, but also to the retorts being larger. Will the author say why the two-stage heating referred to has been discontinued?

With regard to maintenance, I think the eyes of some of us will open when we read that the estimated maintenance of verticals for 20,000 tons is 9·6d. per ton using Derbyshire coal, and 11·2d. per ton carbonizing Durham coal, against 9·7d. carbonizing Durham coal in horizontals. I presume the horizontal retorts which the author used were made of fireclay. If not, were they of silica sections? The question of refractory materials is most interesting to me. Has the author used silica section retorts? If so, has he experienced the same difficulty with regard to expansion? Has he found that the expansion has been less than was anticipated in the case of the verticals? I should like to ask the author two point blank questions. Do I understand that he is using Derbyshire coal to-day rather than Durham coal, which latter he can get at a cheaper price; and if so, why? Secondly, has the author definitely come to the conclusion that vertical retorts constructed in silica are *the* thing so far as he is concerned? If so, will he kindly say why he has come to that conclusion when compared with verticals constructed of Glenboig material and using Derbyshire coal? The estimated cost of repairs will probably be rather more than ½d. per ton of coal carbonized, and the cost per therm slightly more. Those of us who know Mr. Carmichael, and the works which he controls, expected much of him when we learned he was to read a paper to-day; and I can safely say that none of us has been disappointed.

Mr. P. S. HOYTE (Plymouth): I should first of all like to refer to the use of screened coal for the verticals and of the screenings in the horizontal plant. I should like some information as to the size of the screen used, which, I have no doubt, the author will tell us. I should also like to know why he abandoned the rotary screen. As a matter of fact, I think I can easily guess the reason. Large Durham coal is very friable, and he found his percentage of fines increasing substantially after it had been through the rotary screen. He now discharges his coal over a fixed screen; but I should like to know if he has any trouble when the cargo arrives exceptionally damp. Respecting ash in the coke, are not the results with the carburetted water gas plant materially affected by using coke containing 16·3 p.ct. of ash, as compared with the very much lower percentage of ash in his vertical coke? I am sure this raises a question which is in the minds of many of us with regard to the use of horizontal-cum-vertical-cum-water gas installations. I think one of Oscar Wilde's aphorisms was that three addresses inspired confidence in tradespeople; but you have to be particularly opulent to be able to maintain three different types of plant such as verticals, horizontals, and water gas plant. Mr. Carmichael is passing on the screenings from his Durham coal to the horizontal retort house; and this implies that he has to keep the two houses constantly at work, or otherwise store a very large proportion of screenings. Perhaps the author will give us the percentage of screenings actually passed to his horizontal retort house, which, of course, will give us the percentage of Durham coal that goes to the verticals.

There are a few points in connection with the paper upon which I should like some information. Fortunately for the author, he has only given me six days in which to study this paper. I should have preferred six weeks. However, with reference to the labour employed on the plant, this may be largely a question of accountancy, but he only has one leading hand per 24 hours, who is responsible for the working of the plant during the night shift, for adjustment of the dampers in case of boiler breakdown and for putting retorts off for scurfing. When carbonizing Durham coal, I imagine the top and bottom men have sufficient work in attending to the retorts properly, and in cleaning up. Again, the author only allows one telpher driver per 24 hours. Does this mean there is one driver per shift, and he only spends one-third of his time on the vertical plant? This again may be a question of accountancy. The coke in No. 3 installation is drawn from the retorts direct into the telpher skips. Consequently there must be a telpher in readiness for every discharge. How often is the coke drawn from the retorts? Two men only are allowed for scurfing and odd work. Is all the scurfing done by the steaming process? If not, can one man fill the retorts with coke, and restart them? Who does all the greasing of the extractor gear and machinery on plant other than the coal plant? We have one man fully occupied on this all the week.

It is stated that 70 p.ct. of the steam escapes unaffected at the top of the retort when steaming at (say) 100 lbs. per hour. Does not this give trouble with hanging charges and badly stopped pipes? With Durham unscreened coal, a small excess of steam gives us stopped pipes very quickly. I should like to know why the two-stage heating was given up. The Glover-West system employs it with success, and it is the only way of getting nearly uniform heating.

There is only one other point, but it is a very important one—viz., assuming that two plants are in use, what is your coal cost going to be? It does not matter whether you have verticals or horizontals or both, as well as carburetted water gas plant. The point is, What are you going to pass the coke to your C.W.G. plant at? The author says that if you drop the price of coke to the latter, it will decrease the cost of the carburetted water gas. This, of course, will increase the cost of your coal gas. It is a two-edged sword; and if you drop the price of coke from 30s. to 25s. per ton, your coal gas suffers by a decreased credit, and the water gas is improved by an increased credit. At Plymouth I have found it absolutely hopeless to try to separate the two processes. You have to make up a series of

tables showing the varying percentages—within limits—as to what the coke could be sold at, and the varying percentages of coal gas and carburetted water gas, and the amount of residuals in each case; but it is an extremely difficult matter. If you make a higher percentage of carburetted water gas, at certain states of the market you get less credits for residuals, while at other times it is necessary to make a larger percentage of coal gas. As a matter of fact, we work very largely on these lines, adhering closely to our standard of 450 B.Th.U. This is a matter which closely concerns all of us—not only those who have these plants, but also those who may be contemplating putting in C.W.G. installations.

Mr. C. M. D. BELTON (Shrewsbury): I should like to pay my humble tribute to the author for an intensely interesting paper, concerning which I should like to ask one or two questions. With regard to the waste-heat boiler, the author states that the greater part of the waste-heat steam is utilized on the plant itself to produce the stated thermal yield. It seems to me that this is rather unnecessary. It appears a small output of steam from the waste-heat boilers or else an excessive consumption on the vertical retorts. In my own case the power required for the fan of the waste-heat boiler is taken from the steam generated in that boiler, and 25 p.ct. of the production is used in driving the fan. The exhaust steam is more than sufficient for all the jets supplying the vertical retorts, and leaves a quantity of low-pressure steam available for a pump. On the question of scurfing, I should like to ask the author if he has had sufficient experience with his silica retorts to say whether he finds that the period elapsing between scurfing is longer or shorter since he increased the depth of the silica material in the retort. There seems to be a good deal of room for research in this matter, because we have not yet got the ideal refractory for verticals. I have tried several kinds, and I think I am in a position to determine for myself what I would use in the various sections of the retort when I have to rebuild. One other item has been referred to—viz., the coke for the C.W.G. plant. It certainly seems that a better yield of gas is available on a time basis when using coke from horizontals or inclines; but the coke usually obtained from vertical retorts is of a clean nature, and does not require so much heat in the generator, on account of the less degree of moisture content.

Dr. A. PARKER: I have read the paper with great interest; and the main point I should like to refer to is the question of grading coal into two sizes—viz., the screened Durham coal and the screenings, which were carbonized in the verticals and the horizontals respectively. The author gives the production in therms with the unscreened coal and the screened coal in the verticals; and one notices a considerable increase in thermal yield as a result of the screening. This, of course, is much more than equivalent to the small reduction in thermal yield through using the screenings in the horizontals. We in Leeds have been carrying out experiments on the effect of sizing coal in an experimental horizontal retort; and I think part of this improvement in thermal yield due to taking out the smalls may be explained from our experiments. We found that if we grade coal into (say) two sizes—$\frac{3}{4}$ to $1\frac{1}{2}$ in. and from 10 to 30 mesh per in.—and carbonize these two sizes separately under identical conditions, the rate of gas production is greater with the large than with the small.

The point which is not so obvious at first sight is that if one mixes these two sizes in equal proportions—50 p.ct. of each—and carbonizes the mixture under the same conditions as the separate sizes were previously carbonized, the rate of gas production is less with the mixture than with either of the two constituents. It would thus appear that a beneficial effect might be obtained as regards throughput in the retort or rate of gas production per retort by sizing the coal in this manner, quite apart from an obvious advantage in the case of the vertical retort of obtaining a better steam decomposition by using a screened coal. I have brought this forward because it is of interest to us in carrying out our experiments; and we are glad to see that Mr. Carmichael has done so much on the large scale. Though the conditions are not identical, yet similar conclusions might be drawn from his figures as from those which we have obtained at Leeds.

Mr. J. W. WHIMSTER (Bath): Most of the speakers have referred to vertical retorts. I have no vertical retorts, so I will not worry Mr. Carmichael with any questions about verticals; but I would like to ask him something with regard to his comparison between verticals and horizontals. I agree with Mr. Warren that this comparison is not in favour of horizontals; but I think this wants looking into very closely, because the cost of working horizontals is given as 0·43d. per therm for labour, as against 0·13d. in the case of the best vertical results, and so is three times as much. I maintain, however, that the modern horizontal retort house can be worked as economically, as far as labour is concerned, as vertical plant. A modern horizontal retort house carbonizing about 240 tons costs about 0·13d. per therm for labour, the same as the author's figure for verticals; and this would bring the total cost, which the author gives as 1·63d. per therm for horizontals, down to 1·34d. per therm, as against the best vertical of 1·54d. On these figures the horizontals would be cheaper.

Mr. H. E. COPP (Hull): I was going to point out respectfully to the author that, instead of sorting out the fines from his coal in order to prevent undue swelling in the vertical retort, this might be effectually accomplished by the admixture of a certain proportion of breeze or screened coke. Of course, the ideal way, as probably our friends from Leeds would say, would be to blend the coals in such a manner that there would be no swelling; but there is a certain amount of difficulty about this. Another point raised by the author in the paper is that some abrasive action or wastage of the retorts has been found 5 ft. or 6 ft. down; and this is attributed to the action of rodding. I suggest that the cause of this may be—I am not speaking at all dogmatically—the heat interchange. At this level there is not such an easy interchange of heat between the inside of the retort and the combustion chamber. Therefore, I have a suspicion that perhaps the action is due to a question of temperature rather than to the mechanical action of rodding. The author also refers to the decomposition of steam. I think it may be suggested that the author's temperature has not reached what I would call the critical temperature for the decomposition of steam. He mentions 1350° C.; but I venture to suggest that, if a higher temperature were worked, a very much more efficient decomposition of steam would be obtained. If you worked your retort at (say) 1450° C., instead of 1350°, you would find a material difference in the decomposition of the steam. I should like to have heard a little more from the author about the advantages of scurfing by means of steam and coke. I have been trying this for a few weeks, and I have a suspicion that it is a most effective way of scurfing retorts in that it does away with practically all the labour.

Mr. H. H. GRACIE (Edinburgh): This is a most excellent paper because the author has put the whole of his facts before us in such an unequivocal manner. I am particularly pleased to hear of the low charges for maintenance. We have not had our retorts sufficiently long to get information on this point; but it is very encouraging to know it is such a small figure. I understand that 70 p.ct. of the steam escapes unaffected at the top of the retort, and I am a little sorry the author did not enlarge on the point of the large amount of virgin liquor which we get from condensation, amounting to 50 gallons per ton of coal. This figure is closely related to what we are getting at Edinburgh. It appears to me that this is a matter into which the Research Committee might inquire, having regard to the low return we are getting for sulphate of ammonia. We find it is costing us from 20 to 25 p.ct. extra for the working-up of this liquor in the sulphate of ammonia plant; and with the low yield we are obtaining from it, there is almost nothing left. I was very much interested to hear the last speaker say what he did with regard to the higher temperature for cracking the steam. As a matter of fact, we are working our verticals at from 1440° to 1450° C., and we are not getting rid of the steam. Therefore, it seems there is a point here which requires a great deal more investigation.

Mr. W. M. CARR (Stretford): I should like to say a few words with regard to the comparison in the paper. I somehow feel that comparisons are always odious; and although in the present instance they may be excellent, at the same time I feel they may be very deceptive. The reason I mention this is that I am looking at the matter from a very different point of view from that of the author. I am concerned with a works which is situated in the midst of the coalfields. Therefore, if I took the author's comparisons as a basis for the results I might hope to get from horizontals and verticals in my particular situation, I might be very much misled. If we are to get the full benefit of these comparisons, I suggest that we have to be very careful about our particular point of view, as depending upon the locality. Mr. Carmichael has made out a very strong case for working horizontals and verticals in conjunction—*i.e.*, dealing with the fines in the horizontals and the larger coal in the verticals, in order to get the most economical all-round results—and there is no doubt about it that where both plants are available it does lead to great economy.

In the comparisons, however, the author has taken his fines at the same value as the rough. After all, the acid test in this matter is the net cost of coal, or, perhaps better still, the final cost of gas into the holder. Perhaps in the case of Portsmouth the cost of the fines would be the same as the cost of the rough; but those of us who are living in the vicinity of the coalfields know that we can buy fines at a lower price than large coal; and therefore the author's figures of comparison do not stand. For instance, at Stretford, looking at my monthly analyses of costs, my net cost of coal in January when the coke market was good, was *minus* 3·19d. per 1000 c.ft. This is for gas of approximately 540 B.Th.U. In February the figure was *minus* 0·49d., and in March it was *minus* 0·33d. In April we had a big drop in the price of coke, and the figure became 2·41d.; the fuel used being largely Yorkshire washed slacks, which give me a better coke than the Durham fines would give. From the horizontals it gives a coke containing less than 10 p.ct. of ash, as the Yorkshire washed slacks contain only 5 to 6 p.ct. of ash.

Therefore, I do feel that we people who live in the vicinity of the coalfields have a different outlook from that of those who live in the South, away from the coalfields; and I am sure Mr. Carmichael will forgive me for making this little criticism of the comparisons from the point of view of horizontals and verticals. In other words, the verticals may have it in one

locality, but it does not mean that they will have it in all localities.

Mr. W. J. SMITH (Bolton): There is one small point in connection with the comparison between the verticals and horizontals to which I should like to draw attention, and that is, Has the coke been valued on the dry basis, because we do find in Lancashire that there is a difficulty in shipping horizontal coke as compared with vertical coke? People will take vertical coke; and I have known works where 12 cwt. of coke were sold per ton, 2 cwt. were used in the furnace, and yet the whole of the coke per ton of coal on the dry basis was only 13 cwt. It is rather difficult to find an equation to fit these conditions. It is important that the coke should be sold on the dry basis. Also, the market value of coke should have been stated in the paper.

Mr. H. CHAMBERLAIN (Sheffield): Could the author add to his interesting figures by giving us a comparison between the percentages of inerts and impurities in the vertical and the horizontal gas? I think that is a very important point; and it might perhaps have a bearing on the question of which is the most economical method in the long run. The figures of sulphur content are particularly important.

The PRESIDENT: It is apparent that I was right when I said that Mr. Carmichael had provided us with plenty of powder and shot. As to whether any of our friends have succeeded in hitting the target, we shall be better able to judge after Mr. Carmichael has replied to the criticism; and without further remarks, I will ask him to reply.

Mr. CARMICHAEL: I am very gratified with the discussion that has taken place. The paper was written to evoke a discussion; and I think we have had a very good and profitable one. The President and others have been very complimentary; and I appreciate what has been said. I can assure you the work has been a very great pleasure indeed. With regard to Mr. Prentice's remarks, I am pleased to hear of his method of separating the fines from Durham coal by raising the ploughs on the conveyors. Of course, the efficiency at Portsmouth of the screening process depends very largely on the amount of coal required in the horizontal and the vertical retort houses. In actual practice, the separation works out at about 50 p.ct. Our usual cargoes are about 2000 tons, and the screen is so arranged that 1000 tons of fines is taken out, and the remainder is allowed to go on to the vertical house. Some cargoes contain a very high percentage of fines, and we do not get absolutely screened coal going to the verticals. I take it that Mr. Prentice is in the same position; he does not get screened coal, but only partially screened coal in actual practice. With regard to mixing non-caking coal with Durham, it certainly helps in increasing the throughput and obtaining better working in a vertical retort; but the difficulty is in mixing properly. It also depends very largely on the state of the inside of your vertical retort. I have seen a retort in such a rough condition that not even non-caking coal would go through without much rodding.

Mr. Warren referred to costs, and said the conclusions were rather startling as between horizontals and verticals. Owing to the coal stoppage I was unable to carry out any tests on the newer horizontal plant at the Hilsea Gas-Works; but I do not consider that a plant carbonizing 81 tons of coal per day is out of date. I think the results are fairly good. The labour costs certainly are high; but if you go into the details of the labour as given in the tables, you will find five or six men under the heading of coal wheelers, and generally I think the actual labour in the retort house is a normal figure. There is certainly a lower ash content in the vertical coke sold, and the water gas plant is penalized in that horizontal coke is used having a higher percentage of ash. Vertical coke, I agree, is highly suitable for water gas plant, but we prefer to sacrifice efficiency in the water gas plant in order to give to our consumers an improved quality of coke.

Mr. Bennett wanted some details of the mesh of the bar screen. The opening between the bars is ¾ in. The bars are V-shaped, and tapered to prevent the small coal choking the screen. The breadth of the bar is ½ in. The coal passes subsequently through the breaker, but most of the small coal is by-passed. There is a division plate in the coal hopper between each four retorts; and when scurfing we have two retorts in one setting working on coal, and the other two scurfing and working on coke. If there is any rise of temperature in the two retorts that are being scurfed, it is a simple matter for the temperature attendant to check it by pushing-in the main check tile dampers. The increase in throughput is very largely due to the silica retorts, and the higher temperature at which we are able to work these retorts. The size of the new silica retorts at the top is 5 ft. by 9 in., whereas the old retorts measure 4 ft. 3 in. by 7 in. At the bottom both silica and fireclay retorts are the same size. Mr. Bennett also referred to two-stage heating. With fireclay retorts, all the heat that was required for carbonizing Derbyshire coal was obtained with the single stage, and it was not necessary to use the two-stage system. With regard to the silica settings, the two-stage heating was discontinued because of the leakages referred to under "Refractories" in the paper. Owing to leakages, very high bottom temperatures are at times obtained.

On the question of refractories, I think the silica refractory is absolutely essential to-day. As Mr. Bennett knows, silica withstands very high temperatures, much higher than does fireclay—as much as 1450° C., and over, and at a load of about 50 lbs. per sq. in. The fireclay will not withstand this. The maintenance cost per ton of coal carbonized with silica is higher than with fireclay over a certain period of years. But in spite of that I would select silica every time; and it is up to the larger companies to bear part of the cost in the event of a slight failure, in assisting to get the material which will stand, and which when obtained will ultimately be to the benefit of the industry.

Mr. Bennett also referred to Derbyshire coal in verticals, and asked why Portsmouth continues to buy Derbyshire coal. This is a question I anticipated. The coal used in the tests previously referred to was Durham, which had been in stock for several years; and the consequent weathering had reduced its caking properties. Little or no trouble was experienced in carbonizing this coal, except that we were unable to steam the coke to any great extent. The average calorific value was 477·5 B.Th.U., though every endeavour was made to get down to 460 gas. It is, however, altogether a different matter carbonizing freshly wrought unscreened Durham under steaming conditions in silica retorts that are not gas-tight. I am, of course, very anxious indeed to obtain for my Company the cheapest therm, and I only wish I could say that Durham coal was now being carbonized in the new silica installation. We are not buying any great quantity of the more expensive coal, for, having a surplus of carbonizing plant, we are in a position to keep in operation such plant as will produce the cheapest therm. From Table III. it will be observed that the cost of the therm produced by working Durham coal in a horizontal plant (1·69d., Col. 8) takes a very good second place to the Durham figures referred to (1·67d., Col. 4). For this reason the horizontals at Hilsea have been kept in operation, and a section of the verticals has been shut down.

We are still experimenting with unscreened Durham in the new vertical plant, and the following figures were recently obtained:

Duration of test	5 days		
Throughput	4 8 tons	..	Guarantee 5 06 tons
Therms per ton	71·5	..	,, 77·8
Calorific value, B.Th.U. .	497·0	..	,, 460
Fuel (ash-free)	2·18	..	,, 2·65

Worked out on the lines of the paper, and taking the residuals as in Col. 4 in the table under the heading of "Calculating Cost of Production," and labour as in the same column—namely, 17 men per 24 hours—the total cost per therm in Tables II. and III. works out at approximately the same as the cost given for stock Durham coal. It was intended to carry on this test for a much longer period, but owing to the difficulty of heat-zoning, and in consequence of the retorts holding up, the plant was turned over to Derbyshire coal at the end of five days. It is hoped, however, soon to establish a set of conditions in this No. 3 installation which will enable us to carbonize the cheaper coal, and so derive the benefit of a cheaper therm than is now being obtained from the use of Derbyshire coal.

I feel certain that most of our trouble is the result of the unfortunate leakages in the settings, which at the moment prevent the proper zoning of temperatures. As freedom from hanging charges is largely a question of correct combustion chamber temperatures, I am of the opinion that when the pointing of these retorts is carried out, much of the hanging and rodding difficulties will disappear. Durham coal will then be used exclusively. For many years Derbyshire coal (as reported in 1922) carbonized in vertical retorts gave the cheapest therm; excellent results being obtained in regard to make and fuel. The difference in the net cost of coal was then only 2s. 8d., but to-day it is 6s. 2d. per ton; and this makes all the difference, ruling Derbyshire coal out of account.

Further Written Reply to Discussion by Mr. Carmichael.

Most of the outstanding points are covered by the opening sentence of the paper, which makes it clear that the results and costs given refer only to plant at the author's disposal. Full details of the plant were given in the hope that other engineers who might wish to use the figures for comparative purposes would be able to modify them in accordance with their own conditions. It was later explained that the horizontal plant tested was of an old type; but it is hardly "obsolescent," since a yield of over 70 therms per ton of coal is obtained therein. The high fuel account in this plant is due partly to the use of cold coke (for reasons explained), and partly to leaky regenerators. As to the amount of coke and breeze for sale, these horizontals were actually credited with a fuel consumption no higher than that of No. 1 vertical installation. The horizontal costs should, therefore, to meet Mr. Warren's point, be higher than those actually given. The use of the poorer class of coke does, in fact, cause more clinker and somewhat lower output in the water gas plant, but I prefer to sacrifice a little in this direction in order to obtain an improvement in the coke sold. The higher percentage of moisture in the coke also causes a little difficulty in "lighting-up" the carburettor.

In reply also to Mr. Bennett, silica segmental horizontal

retorts have not been used at Portsmouth. Mr. Hoyte asked why the rotary screen was discarded. This was principally because the power required to drive the original machine was excessive when compared with that necessary to raise the coal on to a bar screen. Mr. Belton is obviously using a much smaller proportion of steam than is the case at Portsmouth, where the steam represents from 16 to 22 p.ct. of the weight of the coal. The steam balance may be calculated from the figures given, and that used in the retorts is a far greater quantity than the fan exhaust. Incidentally, Mr. Gracie's contribution to the discussion bears out the author's experience in this and other respects. Mr. Copp's suggestion of the use of coke or breeze to attain a greater porosity of the charge is interesting, but it would be difficult to secure proper blending; and a reduced output of the plant would have to be faced. No marked increase in the degree of steam decomposition has been found to result from an increase of 50° or 100° C. in the combustion chamber temperature.

The screenings from Durham coal cost at Portsmouth as much as unscreened coal; but if Mr. Carr can buy screenings at 1s. per ton reduction, it would appear that screened coal should have a correspondingly enhanced value. The author is in agreement with Mr. Smith's remarks on the comparison of coke weights—the coke and breeze for sale mentioned in the paper are corrected to 5 p.ct. moisture in every case. The inerts and sulphur in the gas from continuous vertical retorts have been found to be about 25 to 30 p.ct. less than from horizontals.

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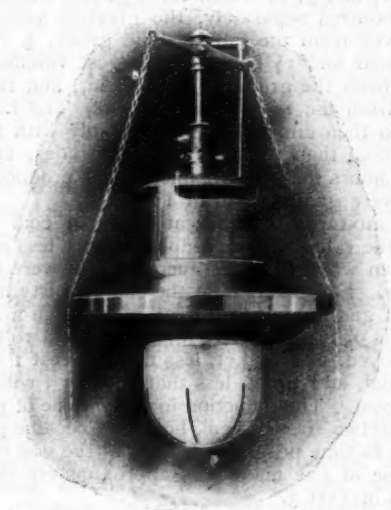

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EIGHTEENTH REPORT OF THE RESEARCH SUB-COMMITTEE OF THE GAS INVESTIGATION COMMITTEE.

STUDIES IN CARBONIZATION.—PART II.

SIZE OF COAL, ADMIXTURE, INORGANIC COMPOUNDS.

SUMMARY.

The work described in this report constitutes the second stage of an investigation commenced with the object of studying the influence of various factors on the yields and physical and chemical properties of the products obtained when different types of coal are carbonized. In the first stage of the investigation, described in the Sixteenth Report presented last year, the principal factor studied was that of variation in the sizes of the particles of coal carbonized with the retort at a temperature of about 980° C. in an experimental plant specially designed for the investigation. The retort, which was cast from an alloy, cronite, of nickel, chromium, and iron, is supported centrally within a fire-clay retort in such a manner that an annular space of 1½ in. surrounds the metal and separates it from the fireclay. The temperatures recorded were taken by means of a thermo-couple placed in the annular space surrounding the metal retort. The temperatures of the combustion chambers were, of course, much higher.

The first series of experiments was conducted with a Nottinghamshire gas coal of moderate coking properties. When carbonized in full-scale horizontal retorts, this coal yields approximately 12·2 cwt. of coke per ton, 12·7 gallons of tar, and gas with a gross heat value of 70 therms.

The thermal value of the gas made per ton of coal was higher in the tests described in the Sixteenth Report than when the same coal is carbonized in full-scale horizontal retorts. The thermal value of the total gas made increased from 72·3 therms per ton with the grade of coal 1¼ in. to ¾ in., to 75·8 therms with the grade 10 to 30 mesh; but this increase in the thermal value of the gas with the smaller sizes of coal was accompanied by a decrease in the yield of tar.

In the early stages of carbonization, the rates of gas production were greater with the larger sizes of coal than with the smaller sizes. For example, the volume of gas made when the carbonization had proceeded for one hour was 12 p.ct. greater with the 1¼ in. to ¾ in. coal than with the grade 10 to 30 mesh. The rates of gas production decreased as time progressed, but not so rapidly with the smaller sizes; and at the end of the carbonization the total volumes of gas produced from the smaller sizes of coal were greater than from the largest grade.

Experiments were also made to determine the effect of altering the temperature of the retort by about 25° C. This comparatively small change in temperature had a marked effect on the rate of gas production in the early stages. At the end of half an hour, 10 p.ct. more gas had been evolved from the ½ in. to 10 mesh coal with the retort at 1000° C. than at 977° C. The differences in volumes of gas made, however, became proportionately less as time progressed, until at the end of 2¾ hours the total volumes were approximately the same at the two temperatures.

The structure of the cokes produced from the different sizes of coal was also examined. The coke from the 10 to 30 mesh coal was more uniform in structure than that obtained from the larger sizes.

During the past year the investigation has been continued with the same Nottinghamshire coal; but the experiments have been conducted with the retort at approximately 915° C. The experiments were arranged to obtain information on the influence of

(*a*) grading the coal in different sizes,
(*b*) the admixture of different sizes,
(*c*) the temperature of the retort,
(*d*) the addition of coke breeze to the coal, and
(*e*) the addition to the coal of calcium carbonate, iron oxide, and sodium carbonate.

Influence of Size of Particles of Coal.—The coal was graded in four sizes, 1¼ in. to ¾ in., ½ in. to ¼ in., 10 to 30 mesh, and through 30 mesh, in such manner that the compositions of the four grades determined by analysis were practically the same. The first three grades were carbonized separately in Tests 1, 2, and 3; and the four grades were employed in the preparation of mixtures of sizes for Tests 4, 5, 6, and 7.

The volumes of gas made in Tests 2 to 7 did not differ greatly from one another, and averaged 11,940 c.ft. per ton of coal; but in Test 1, with the largest grade of coal, the volume of gas obtained was only 11,270 c.ft. In the previous experiments at 980° C., the smallest volume of gas was also produced by the largest grade of coal. The thermal value of the gas in Tests 2 to 7 averaged 71·2 therms per ton of coal; the heat value of the gas produced in Test 1 was only 67·3 therms; but the largest yield of tar was obtained in this test. The total yield of ammonia was approximately the same in the seven tests, and was equivalent to an average of 25·2 lbs. of ammonium sulphate per ton of coal.

The average figures for the volumes of purified gas made from separate charges, each of 30 lbs. of coal, as carbonization progressed, are given in the following table:

Gas Made in C.Ft. per 30 Lbs. of Coal as Charged.

Size of Coal.	1¼ to ¾ In.	½ to ¼ In.	10 to 30 Mesh.	Mixtures of Sizes.			
Test	1	2	3	4	5	6	7
Time of Carbonization. Hrs. Mins.							
0 30	60·7	60·9	55·2	52·4	54·6	54·5	50·7
1 0	101·0	99·3	91·9	86·7	89·8	89·8	85·1
1 30	130·8	129·5	122·9	115·1	118·9	119·2	114·5
2 0	143·4	150·7	147·3	138·0	141·0	143·1	139·5
2 30	140·8	155·9	154·6	154·1	156·4	150·1	158·1

During the first thirty minutes of carbonization in Tests 1, 2, and 3, in which three grades of sizes of coal were carbonized separately, the greatest volume of gas was evolved from the intermediate grade, ½ in. to ¼ in. After 1 hour and 1½ hours, the largest volume had been obtained from the grade 1¼ in. to ¾ in., and the smallest volumes from the 10 to 30 mesh coal. The rates of gas production then diminished more rapidly with the largest grade of coal than with the smaller grades, until at the end of 2½ hours the total volumes of gas produced in Tests 2 and 3 were greater than in Test 1.

When mixtures of different sizes of coal were carbonized, the rates of gas production were less in the early stages than when the constituent grades were carbonized separately. For example, at the end of thirty minutes the volume of gas produced in Test 4, in which a mixture of equal parts of the grades 1¼ in. to ¾ in. and 10 to 30 mesh was employed, was 14 p.ct. less than in Test 1 with 1¼ in. to ¾ in. coal, and 5 p.ct. less than in Test 3 with the 10 to 30 mesh coal. The reduction in the volume of gas, due to mixing the two sizes of coal, however, became proportionately less as time progressed, until at the end of 2½ hours the volume of gas made was approximately the same in Test 4 as in Test 3.

Influence of Temperature.—A comparison of the results obtained in the tests described in the Sixteenth Report with those conducted during the past year shows that a reduction of about 60° C. in the temperature of the retort from 980° C. caused a diminution of approximately 750 c.ft. in the volume of gas made per ton of coal; and the thermal value of the gas made was diminished by about 4 therms. The yields of tar were greater at the lower temperature.

In the early stages of carbonization, the rates of gas production were greatly reduced by lowering the temperature of the retort by 60° C. At the end of five minutes the volumes of gas obtained averaged 22 p.ct. less at the lower temperature; but this difference became smaller as time progressed, until at the end of 2½ hours it had fallen to 7 p.ct.

Mixtures of Coal and Coke.—It has been concluded

from the work of previous investigators that by mixing coal of a highly caking character with coke breeze, the carbonization of the coal can be completed more rapidly and with increased rates of gas production. Although the Nottinghamshire coal used in the investigation described in this report is not of a highly caking quality, it was considered desirable to determine the influence of admixture with coke. For this purpose, the 10 to 30 mesh coal employed in Test 3 was mixed with 10 to 30 mesh coke prepared from the same coal. Two mixtures containing 10 p.ct. and 20 p.ct. of coke were carbonized in Tests 8 and 9 respectively. Owing to the greater volume occupied by coke as compared with coal, it was necessary to reduce the weight of each charge in Test 9. This point is of importance when considering the admixture of coal and coke in commercial practice. The yields of gas, expressed in cubic feet and therms, and of ammonia per ton of coal contained in the mixtures, were a little greater in Tests 8 and 9 than in Test 3. Smaller yields of tar, however, were obtained from the mixtures with coke than from the coal alone. The volumes of gas evolved from each charge at corresponding periods of carbonization were less with the coal-coke mixtures than with the coal only; but it must be remembered in this connection that individual charges in the three tests did not contain the same weight of coal.

From the results obtained in Tests 3, 8, and 9, it may be concluded that the disadvantages more than counterbalance the advantages which result from the admixture of coke with the *particular coal* used in these experiments.

Mixtures of Coal with Calcium Carbonate, Iron Oxide, and Sodium Carbonate.—For the purpose of examining the process of carbonization of the Nottinghamshire coal after admixture with calcium carbonate, iron oxide, and sodium carbonate, separate mixtures of the 10 to 30 mesh coal were made with amounts of these three compounds equivalent to 2 parts by weight of the corresponding oxides to 98 parts of coal. These mixtures were then carbonized in Tests 10, 11, and 12 under the same conditions as in Test 3 with the coal alone. The weights of charges employed were such that each charge contained 30 lbs. of coal.

The added compounds caused increases in the volume of gas made per ton of coal; but the gas was of a lower calorific value per cubic foot. The increases in gas volume with calcium carbonate and iron oxide were equivalent to 11 p.ct. and 6 p.ct. respectively. The largest increase in the volume of gas produced resulted from the addition of sodium carbonate in Test 12, which gave 24 p.ct. more than in Test 3. The thermal value of the gas as a result of the addition of calcium carbonate represented an increase of 5 p.ct.; and with iron oxide the increase was of 2 p.ct. With sodium carbonate, the thermal value of the gas per ton of coal was 78·7 therms, or 12 p.ct. more than from the coal without addition. The quantity of sulphuretted hydrogen in the crude gas was reduced from 400 grains per 100 c.ft. to approximately half this amount by the additions of the three compounds considered.

The yields of ammonia in the tests in which iron oxide and sodium carbonate were added to the coal were a little greater than in Test 3; but the yield which resulted from the addition of calcium carbonate was 35 p.ct. more than with the coal alone.

The total volumes of gas evolved from the same weight of coal at all stages of carbonization were greater with the mixtures containing calcium carbonate, iron oxide, and sodium carbonate than from the coal without addition. Sodium carbonate was most effective in this respect; the volume of gas was 8 p.ct. more at the end of five minutes and the extra volume made steadily increased to over 20 p.ct. at the end of 2½ hours.

As a result of the added compounds, the cokes produced in Tests 10, 11, and 12 contained larger quantities of ash and sulphur than the amounts in the coke made in Test 3. The nitrogen contents of the calcium carbonate and iron oxide cokes were lower than of the coke from the coal alone; but sodium carbonate produced no appreciable change in this respect.

Examination of Coke.—A brief account is given at the end of this report of work in progress with the object of determining differences in the physical structure, reactivity towards steam and carbon dioxide and "ignition temperature" of the cokes made during the investigation. The experiments so far conducted have shown that lowering the temperature of the retort by 60° C. caused an increase in the reactivity of the coke towards steam; and greater increases in reactivity resulted from the additions of calcium carbonate, iron oxide, and sodium carbonate, in ascending order as named. Lime and iron oxide both produced a lowering of the "ignition temperature" of the coke; but it is remarkable to find that sodium carbonate coke, which was the most reactive towards steam, gave an "ignition temperature" much higher than the coke obtained from the coal without addition. When this section of the work has reached a further stage, a more complete account will be given.

DETAILED DESCRIPTION OF INVESTIGATION.

Research Chemist: A. PARKER.

Research Assistants: H. KERR and C. B. MARSON.

INTRODUCTION.

The object of the investigation, of which the second stage is described in this report, is a study of the various factors which may influence the yields and physical and chemical properties of the products obtained when coal is carbonized. Among the many factors which must be taken into account in a complete study of the subject, the following are being given consideration.

1. The physical state of the coal to be carbonized as determined by the average size and the variation in sizes of the particles.
2. The nature and quality of the coal as determined by the source from which it is obtained.
3. The temperature and duration of carbonization.
4. The mixing of different types of coal with one another and with coke in various proportions.
5. The effect of briquetting with and without a binder.
6. The nature of the inorganic constituents of the coal and the effect of adding inorganic compounds.

The efficient mixing of different types of coal with one another and with coke or other substances in various proportions cannot be accomplished without the preliminary disintegration of the ingredients to reduce the particles to relatively small sizes. The first step in the investigation is, therefore, to determine the variations in the yields and qualities of the products obtained when particular coals in graded sizes of particles are carbonized under the same conditions.

In an investigation of the type under consideration, the most accurate control of all factors is important. It was therefore necessary to construct an experimental carbonization apparatus specially designed to meet the requirements. When the fundamentals have been studied in the experimental plant, the factors which prove to be of greatest importance may be selected and examined in a full-size commercial plant. With the requirements in view, the research staff designed and erected the apparatus described in detail in the Sixteenth Report.

EXPERIMENTAL RESULTS.

The carbonization experiments which constitute the second stage of the investigations have been carried out with the experimental plant arranged exactly as described in the Sixteenth Report, no alterations to the plant having since been made. The methods of grading the coal, making measurements and weighings, sampling and analysis, and operation of the plant have also been retained, and the same Nottinghamshire coal has been used throughout.

During the past year, however, the experiments have been conducted with the retort at a temperature of approximately 915° C., whereas in the previous tests the temperature of the retort was about 980° C. The experiments were arranged with the object of obtaining information regarding the influence of (*a*) grading the coal in different sizes, (*b*) the admixture of graded sizes, (*c*) the temperature of the retort, (*d*) the addition of coke breeze to the coal, and (*e*) the addition to the coal of calcium carbonate, iron oxide, and sodium carbonate.

INFLUENCE OF SIZE OF COAL.

The principal results of the tests designed to determine the influence of the size of the coal and of the admixture of different sizes are set out in Table I. Four grades of sizes, 1¼ in. to ¾ in., ½ in. to ¼ in., 10 to 30 mesh, and through 30 mesh, were prepared in such manner that the compositions of the four grades of coal were as nearly as possible the same. The first three grades were carbonized separately, and the results given for Tests 1, 2, and 3 were

obtained. The different grades were then used in the preparation of mixtures of sizes carbonized in Tests 4, 5, 6, and 7. The compositions of the mixtures used were as follows:

Test 4, equal parts of 1½ in. to ¾ in. and 10 to 30 mesh.
" 5, " " ¾ " " ¼ " " 10 to 30 "
" 6, " " 1½ " " ¾ in., ¾ in. to ¼ in., and 10 to 30 mesh.
" 7, " " each of the four grades of sizes.

The figures given for the temperatures of the retort represent the averages of the temperatures recorded, at the eight points of measurement in the annular space surrounding the cronite retort, at the beginning and the end of the period of carbonization of 2½ hours of each charge. The weight added, at the commencement of each experiment, to the governor in the gas supply service to the burners of the setting, and the adjustment made in the air supply to the burners, were such as to ensure that the temperature of the retort was the same at the end of the period of carbonization as at the beginning.

The amounts of moisture and ash in the coal as charged into the retort were practically the same in all tests.

The volumes of gas made showed little variation in Tests 2 to 7, and averaged 11,940 c.ft. per ton of coal carbonized; but in Test 1 with the largest grade of coal, 1½ in. to ¾ in., the volume of gas obtained was only 11,270 c.ft. In the previous carbonization experiments with the retort at 980° C., the largest grade of coal also gave the lowest yield of gas. The quality of the gas made was approximately the same in all seven tests, and averaged 597 B.Th.U. (gross) per c.ft. The thermal value of the gas made per ton of coal carbonized averaged 71·2 therms gross in Tests 2 and 7, but in Test 1 the lower value of 67·3 therms was obtained.

The results of analyses of the purified gas made during the different tests do not exhibit any important differences in composition. The value of m in the formula C_mH_n for hydrocarbons absorbed by bromine was approximately 3·0. The value of n in the formula C_nH_{2n+2}, representing the composition of the methane hydrocarbons, averaged 1·05. The methane hydrocarbons may, therefore, be represented by the expression $C_{1\cdot05}H_{4\cdot10}$, which is equivalent to a mixture containing 95 p.ct. of methane and 5 p.ct. of ethane. The amount of carbon dioxide removed by the solutions of caustic soda circulated in the purifiers has been included in the figures given to represent the volumes of gas produced; and the corresponding corrections have been made in the figures for the compositions and calorific values of the gas.

The yields of dry coke per ton of coal averaged 13·0 cwt. for the seven tests.

The largest quantity of tar, 10·8 gallons, was obtained in Test 1 with the grade of coal 1½ in. to ¾ in. The total amount of pitch removed from the gas off-takes during the seven tests was equivalent to 33 lbs. per ton of coal carbonized. If this pitch be assumed to have a density of 1·3, then 33 lbs. would occupy a volume of 2·5 gallons.

The volume of liquor collected averaged 23·9 gallons per ton of coal. The moisture in the coal, 5·6 p.ct., was equivalent to 12·5 gallons per ton, so that the amount of liquor produced during the carbonization of the dry coal must have been 11·4 gallons. The total yield of ammonia contained in the liquor and removed from the gas by means of sulphuric acid was equivalent to an average amount of 25·2 lbs. of ammonium sulphate per ton of coal carbonized.

Size of Coal and Rates of Gas Production.

During the progress of carbonization of each charge of 30 lbs. of coal the readings of the two gas meters were taken at intervals of five minutes for the first fifteen minutes, and at intervals of fifteen minutes for the remainder of the carbonization period. The volumes of gas passed through each of the meters were then corrected to the standard conditions of 60° Fahr. and 30 in. mercury; and from the corrected readings the total volumes of gas made at the different stages of carbonization were obtained. These volumes, given in Table II., represent the amounts of gas which passed through the meters. They do not include the carbon dioxide removed in the purifiers; but since the volumes of carbon dioxide absorbed by caustic soda were approximately the same in all experiments, the figures in Table II. are comparable.

TABLE II.—*Gas Made in C.Ft. per 30 Lbs. of Coal as Charged.*

Size of Coal.	1½ to ¾ In.	¾ to ¼ In.	10 to 30 Mesh.	Mixtures of Sizes.			
Test . .	1	2	3	4	5	6	7
Time of Carbonization. Hrs. Mins.							
0 5	12·6	15·5	14·5	13·0	14·4	13·6	12·4
0 10	24·3	27 5	24·7	22·8	24·8	23·9	21·9
0 15	34·7	37·1	33·5	31·3	33·4	32·7	30·1
0 30	60·7	60·9	55·2	52·4	54·6	54·5	50·7
0 45	82·3	81·2	74·4	70·5	73·0	72·9	68·8
1 0	101·0	99·3	91·9	86·7	89·8	89·8	85·1
1 15	117·1	115·2	108·2	101·6	105·2	105·1	100·4
1 30	130·8	129·5	122·9	115·1	118·9	119·2	114·5
1 45	139·9	142·2	136·4	127·3	131·0	132·1	127·6
2 0	143 4	150·7	147·3	138·0	141·6	143·1	139·5
2 15	145·4	154·0	152·3	147·2	150·5	151·5	149·9
2 30	146·8	155·9	154 6	154·1	156·4	156·1	158·1

From the figures given in Table II. for Tests 1, 2, and 3, in which three grades of sizes of the coal were carbonized separately, it will be observed that, at all stages of carbonization during the first thirty minutes, the greatest volumes of gas had been evolved from the intermediate grade ¾ in. to ¼ in. in Test 2. During the first ten minutes, the smallest amount of gas was obtained in Test 1 with the largest grade of coal. At the end of forty-five minutes,

TABLE I.—*Results per Ton of Coal as Charged.*

Size of Coal	1½ to ¾ In.	¾ to ¼ In.	10 to 30 Mesh	Mixtures of Sizes.			
Test	1	2	3	4	5	6	7
Temperature of retort, °C.	911	917	918	909	912	912	918
Time of carbonization, hours	2·5	2·5	2·5	2·5	2·5	2·5	2·5
Moisture in coal, p.ct.	5·3	5·8	5·8	5·6	5·8	5·7	5·2
Ash in coal, p.ct.	3·9	3·9	3·9	3·9	3·9	3·9	4·0
Gas made per ton of coal, c.ft. (60° Fahr., 30 in.)	11,270	11,980	11,880	11,800	11,990	11,910	12,070
Composition of gas—volumes p.ct.:							
CO_2	3·6	4·0	3·5	3·7	3·8	3·2	3·4
C_mH_n	4·5	4·7	4·4	4·8	4 9	4·8	4·6
O_2	0·5	0·1	0·3	0·3	0·3	0·3	0·3
CO	11·4	11·4	11·7	11·7	11·8	12·2	11·7
H_2	50·6	52·0	51·2	51·0	50·7	51·0	51·1
C_nH_{2n+2}	27·7	26·6	27·5	27·4	27·3	27·6	27·5
N_2	1·7	1·2	1·4	1·1	1·2	0·9	1·4
	100·0	100·0	100·0	100·0	100 0	100·0	100·0
Calorific value of gas, B.Th.U. per c.ft. gross	597	593	593	601	600	604	589
" " " " " net	538	533	532	542	540	545	531
Thermal value of gas per ton of coal, therms gross	67·3	71·1	70·4	70·9	71·9	72·0	71·1
" " " " " " net	60·6	63·9	63·2	64·0	64·7	64·9	64·1
Specific gravity of gas (air = 1)	0·455	0·450	0·447	0·455	0·459	0·450	0·448
Coke (dry) in cwt. per ton of coal	12·7	13·0	13·0	13·0	13·1	12·9	13·0
Tar (dehydrated) in gallons per ton of coal	10·8	8 6	7·6	6·9	7·2	8·4	6·9
Pitch from gas offtakes, lbs. per ton of coal	33	33	33	33	33	33	33
Ammonia liquor, gallons per ton of coal	24·8	23·1	23·4	24·1	23·9	24·0	24·0
Ammonium sulphate equivalent, per ton of coal, lbs.	25·1	26·6	25·1	23·2	25·3	26·9	24·1
Sulphuretted hydrogen, grains per 100 c.ft. gas	440	390	400	450	470	420	410

the greatest volume had been obtained with the grade 1¼ in. to ¾ in., and the smallest volume from the grade 10 to 30 mesh. The diminution in the total volume of gas made at any time, with reduction in the sizes of coal particles, continued until the carbonization had proceeded for 1½ hours. The rates of gas production then diminished more rapidly, as time progressed, with the largest grade of coal than with the smaller grades, until finally, at the end of the carbonization period of 2½ hours, the total volumes of gas produced in Tests 2 and 3 were greater than in Test 1. The same general conclusions were drawn from the results previously obtained with these three grades of coal when carbonized at 980° C.

When the first three tests, in which graded sizes of the coal were carbonized separately, had been completed, it was considered necessary to conduct experiments with mixtures of graded sizes.

In Test 4 the coal consisted of a mixture of equal parts by weight of the grades 1¼ in. to ¾ in. and 10 to 30 mesh. The figures for Test 4 in Table II. should, therefore, be compared with those for Tests 1 and 3. At the end of five minutes, 13·0 c.ft. of gas had been made in Test 4, as against 12·6 c.ft. in Test 1, and 14·5 c.ft. in Test 3; but at all later stages of carbonization during the first two hours, the total gas evolved from the mixture in Test 4 was considerably less than the volume obtained in either Test 1 or Test 3. In the later stages of carbonization, the rate of gas production was greater with the mixture of sizes; and finally, at the end of 2½ hours, the total volume of gas obtained in Test 4 was approximately the same as in Test 3.

The coal used in Test 5 was a mixture of equal parts by weight of the grades employed in Tests 2 and 3. In Test 5 the total volume of gas made during the first fifteen minutes was approximately the same as in Test 3, but less than in Test 2. The total gas made at any stage of the carbonization during the next two hours, however, was less in Test 5 than in either Test 2 or Test 3.

In Test 6 a mixture of equal parts by weight of the three grades employed in Tests 1, 2, and 3 was carbonized. The figures in Table II. show that the total yields of gas were lower in Test 6 at any stage of carbonization during the first two hours, with the exception of the first five minutes, than in any one of the first three tests.

The coal carbonized in Test 7 consisted of a mixture of equal parts of the three grades used in Tests 1, 2, and 3 and of the grade through 30 mesh. The mixture employed in Test 7 was, therefore, equivalent to 75 p.ct. of the coal carbonized in Test 6 and 25 p.ct. through 30 mesh. The results obtained show that the total volumes of gas produced in Test 7 were less than in Test 6 at all stages of the carbonization during the first 2½ hours.

The general influence of sizes of particles of coal on the total volumes of gas produced as carbonization proceeded is illustrated by the curves given in figs. 1 and 2. The curves in fig. 1 have been constructed from the figures in Table II. for Test 1 (1¼ in. to ¾ in.), Test 3 (10 to 30 mesh), and Test 4, which represents a mixture of the sizes of coal used in Tests 1 and 3, by plotting the total volumes of gas in cubic feet against the times of carbonization. The curves in fig. 2 represent the results obtained in Test 2 (½ in. to ¼ in.), Test 3 (10 to 30 mesh), and with a mixture of these two sizes, Test 5. The curves clearly show the lower rates of gas production obtained when mixtures of sizes are employed than when graded sizes of coal are carbonized separately.

TABLE III.—*Gas Made During Each Fifteen Minutes' Period*

(C.Ft. per 30 lbs. of Coal as Charged.)

Size of Coal.	1¼ to ¾ In.	½ to ¼ In.	10 to 30 Mesh.	Mixtures of Sizes.			
Test . .	1	2	3	4	5	6	7
Period No.							
1	34·7	37·1	33·5	31·3	33·4	32·7	30·1
2	26·0	23·8	21·7	21·1	21·2	21·8	20·6
3	21·6	20·3	19·2	18·1	18·4	18·4	18·1
4	18·7	18·1	17·5	16·2	16·8	16·9	16·3
5	16·1	15·9	16·3	14·9	15·4	15·3	15·3
6	13·7	14·3	14·7	13·5	13·7	14·1	14·1
7	9·1	12·7	13·5	12·2	12·1	12·9	13·1
8	3·5	8·5	10·9	10·7	10·6	11·0	11·9
9	2·0	3·3	5·0	9·2	8·9	8·4	10·4
10	1·4	1·9	2·3	6·9	5·9	4·6	8·2

The figures in Table III. represent the differences in the volumes given in Table II. For example, the volume 26·0 for the second period of fifteen minutes in Test 1 is the difference between the figures 34·7 and 60·7 which appear for this test in Table II. Table III., therefore, shows the rates of gas production expressed in volumes of gas evolved during periods of fifteen minutes, at different stages of carbonization. In the tests in which the three grades of coal were carbonized separately, the highest rate of gas production for the first period of fifteen minutes was obtained in Test 2 with ½ in. to ¼ in. coal. In the second, third, and fourth periods, the largest volumes of gas were evolved in Test 1 with 1¼ in. to ¾ in. coal, and the volumes decreased in Tests 2 and 3 with a reduction in the sizes of the coal particles. The volumes of gas obtained during the fifth period were approximately the same with the three grades of coal; but in each of the succeeding periods there was an increase in the volume of gas produced from the largest grade of coal to the smallest grade.

When mixtures of sizes of the coal were carbonized, the volumes of gas evolved were less during the first five periods of fifteen minutes than in Tests 1, 2, and 3 with the individual sizes. In the sixth, seventh and eighth periods the volumes produced in Tests 4 to 7 were approximately the same as in Tests 1, 2, and 3, respectively; but in the last two periods of fifteen minutes more gas was obtained from the mixtures of sizes than in any one of the first three tests. The nature of the changes which occurred in the rates of gas production, expressed in terms of cubic feet per fifteen minutes, are illustrated by the curves for Tests 1, 3, and 4 in fig. 3, and for Tests 2, 3, and 5 in fig. 4. These curves have been constructed from the results given in Table III.

The maximum and minimum volumes of gas evolved at different stages of carbonization of the charges of coal employed in Tests 1 to 7 inclusive are entered in Table IV.,

TABLE IV.—*Maximum and Minimum Volumes of Gas Produced in Tests 1 to 7 inclusive.*

(C.Ft. per 30 lbs. of Coal as Charged.)

Time of Carbonization.	Maximum.		Minimum.		Difference.
	Test No.	Volume.	Test No.	Volume.	
Hrs. Mins.		C.Ft.		C.Ft.	P.Ct.
0 5	2	15·5	7	12·4	20
0 10	2	27·5	7	21·9	20
0 15	2	37·1	7	30·1	19
0 30	2	60·9	7	50·7	17
0 45	1	82·3	7	68·8	16
1 0	1	102·0	7	85·1	16
1 15	1	117·1	7	100·4	14
1 30	1	130·8	7	114·5	12
1 45	2	142·2	4	127·3	10
2 0	2	150·7	4	138·0	8
2 15	2	154·0	1	145·4	6
2 30	7	158·1	1	146·8	7

in the last column of which the differences in the maximum and minimum volumes are expressed as percentages of the maximum volumes. The figures in this table show that the effects which result in the rates of gas production from changes in the state of division of the coal as charged into the retort are not small, but range from 20 p.ct. in the early stages of carbonization down to 7 p.ct. when carbonization has been completed.

From the figures in Tables II. and III., and the curves shown in figs. 1, 2, 3, and 4, it may be concluded, in general, that in the early stages of carbonization the rates at which gas is evolved diminish as the sizes of the particles of coal are reduced from the grade 1¼ in. to ¾ in. to smaller grades; also, that the rates of gas production from mixtures of sizes are less in the earlier stages than when the constituent grades are carbonized separately. In the later stages of carbonization, however, the rates of gas evolution are greater with the smaller sizes and with the mixtures of sizes than with the larger grades, with the result that, when carbonization has been completed, the total volumes of gas obtained are approximately the same in all instances.

INFLUENCE OF TEMPERATURE.

The carbonization experiments A, C, and E described in detail in the Sixteenth Report were carried out with the same grades of Nottinghamshire coal as in Tests 1, 2, and 3 of this report; but in Tests A, C, and E, the retort was at

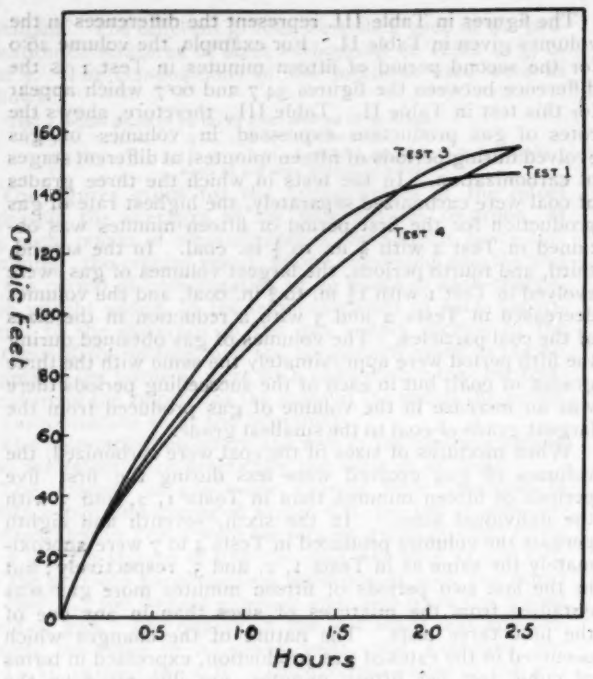

Fig. 1.—Gas Production, Influence of Size of Coal.

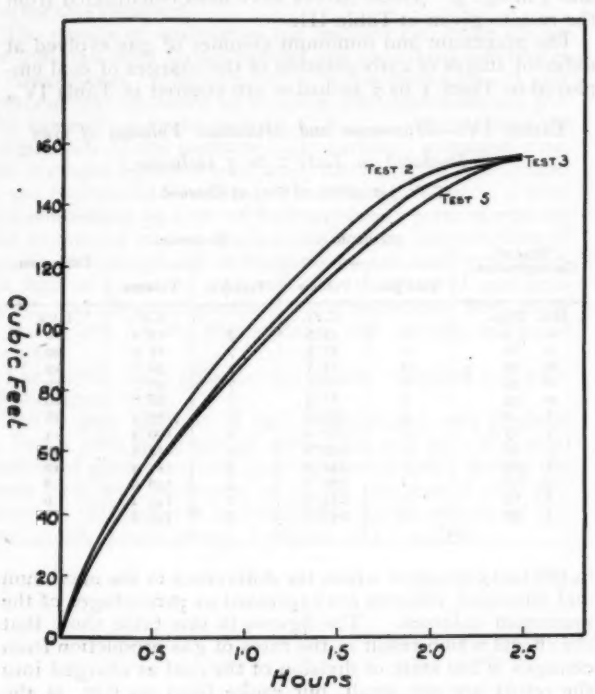

Fig. 2.—Gas Production, Influence of Size of Coal.

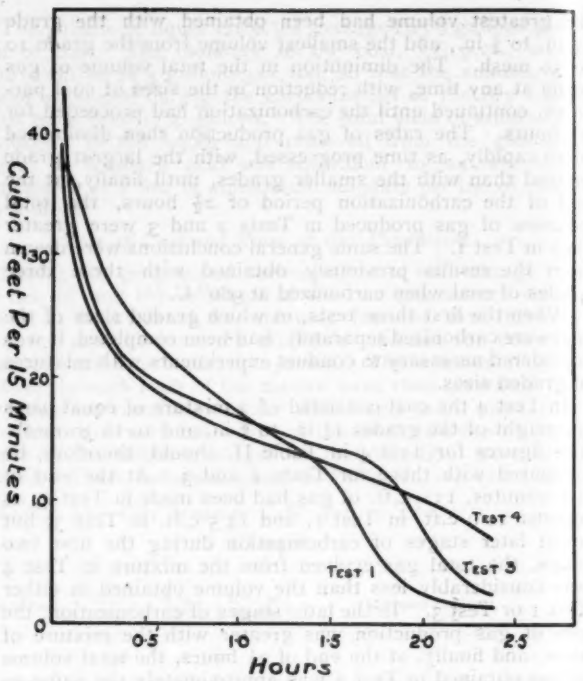

Fig. 3.—Rates of Gas Production, Influence of Size of Coal.

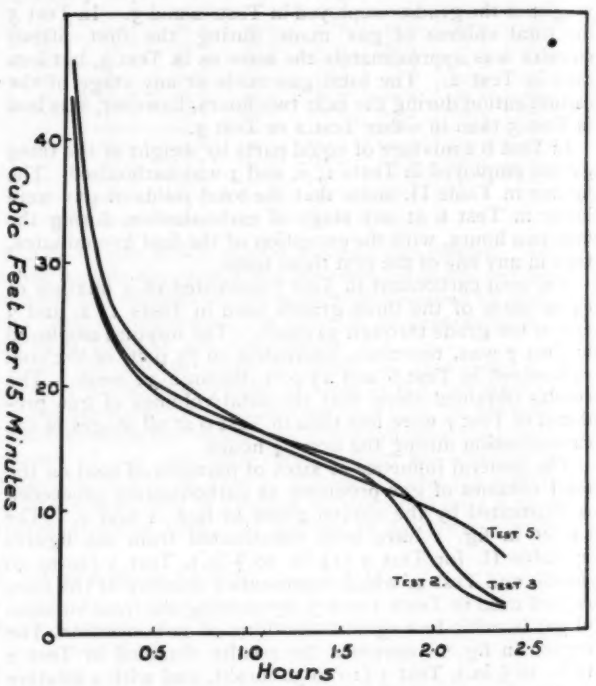

Fig. 4.—Rates of Gas Production, Influence of Size of Coal.

a temperature of 978° C. and the period of carbonization of each charge was 2¾ hours, whereas in Tests 1, 2, and 3 the temperature of the retort was about 915° C. and the period of carbonization was 2½ hours. In Tests G and H of the Sixteenth Report, the same grades of coal were employed as in Tests C and E and Tests 2 and 3, and the temperature conditions of the retort were retained the same as in Tests C and E; but the period of carbonization was reduced to 2 hours. A comparison of the results obtained in Tests A, C, E, G, and H of the Sixteenth Report and Tests 1, 2 and 3 of this report thus enables the influence of a reduction of about 60° C. from 978° C. to 915° C., in the temperature of the retort to be determined. Comparing the principal results of Tests A, C, E, G, and H with those given in Table I. for Tests 1, 2, and 3, it will be observed that the reduction in the temperature of the retort resulted in the production of smaller volumes of gas of lower total thermal values per ton of coal carbonized. The volumes of gas obtained at 915° C. and with a carbonization period of 2½ hours averaged approximately 400 c.ft. per ton less than at 978° C. and a period of carbonization of 2 hours; and the thermal values of the gas made per ton of coal carbonized were lower by an average of about 2½ therms. With a carbonization period of 2¾ hours and a retort temperature of 978° C. in Tests A, C, and E, the volumes of gas produced averaged about 750 c.ft. per ton more than in Tests 1, 2, and 3, and the total thermal value of the gas made was greater by approximately 4 therms. The yields of tar, however, were greater at the lower temperature than at the higher temperature. For example, with the grade of coal 1¼ in. to ¾ in., the volume of tar obtained with the retort at 976° C. was 8·3 gallons per ton of coal, as against 10·8 gallons when the temperature of the retort was 911° C.

Temperature and Rates of Gas Production.

The total volumes of gas made from each charge of 30 lbs. of coal at the different stages of carbonization of

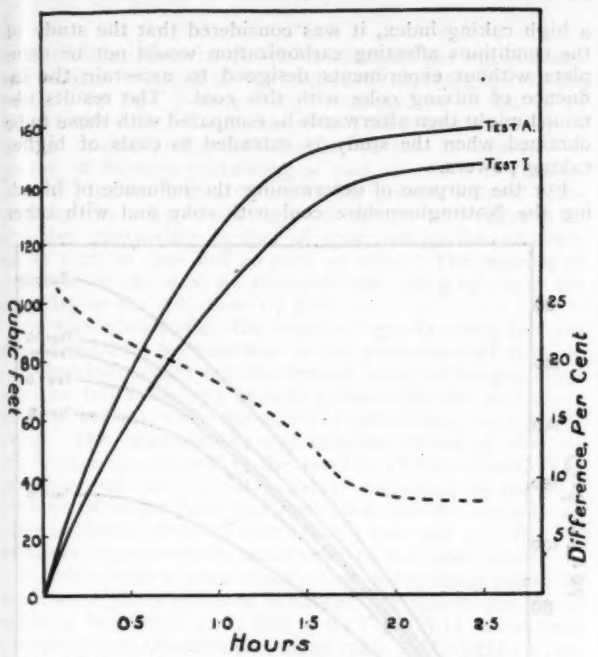

Fig. 5.—Gas Production, Influence of Temperature.

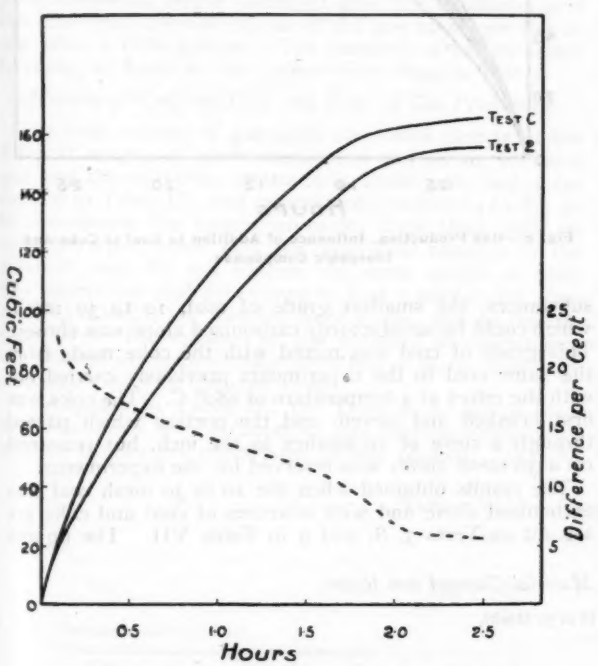

Fig. 6.—Gas Production, Influence of Temperature.

the three grades used in Tests 1, 2, and 3 with the retort at about 915° C. are entered in Table V., together with the

TABLE V.—*Gas Made in C.Ft. per 30 Lbs. of Coal as Charged.*

Size of Coal	1¼ to ¾ In.		½ to ¼ In.		10 to 30 Mesh.	
Test	A	1	C	2	E	3
Temp. of Retort, °C	976	911	978	917	979	918
Time of Carbonization Hrs. Mins.						
0 5	17·1	12·6	20·1	15·5	17·4	14·5
0 10	32·4	24·3	34·5	27·5	30·5	24·7
0 15	45·5	34·7	46·0	37·1	41·3	33·5
0 30	77·6	60·7	74·2	60·9	66·9	55·2
0 45	102·8	82·3	95·8	81·2	88·7	74·4
1 0	123·4	101·0	115·4	99·3	108·0	91·9
1 15	139·5	117·1	132·2	115·2	125·5	108·2
1 30	150·3	130·8	146·3	129·5	141·2	122·9
1 45	154·7	139·9	157·1	142·2	153·7	136·4
2 0	156·9	143·4	161·7	150·7	160·9	147·3
2 15	158·4	145·4	163·9	154·0	163·6	152·3
2 30	159·5	146·8	165·4	155·9	165·3	154·6

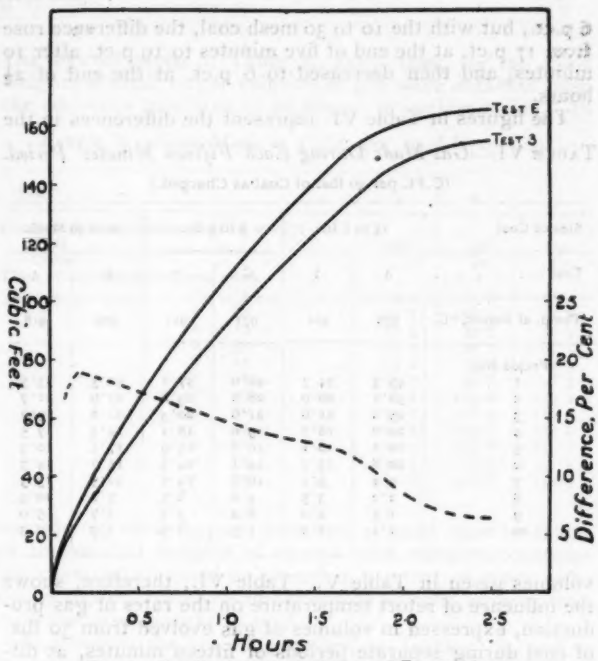

Fig. 7.—Gas Production, Influence of Temperature.

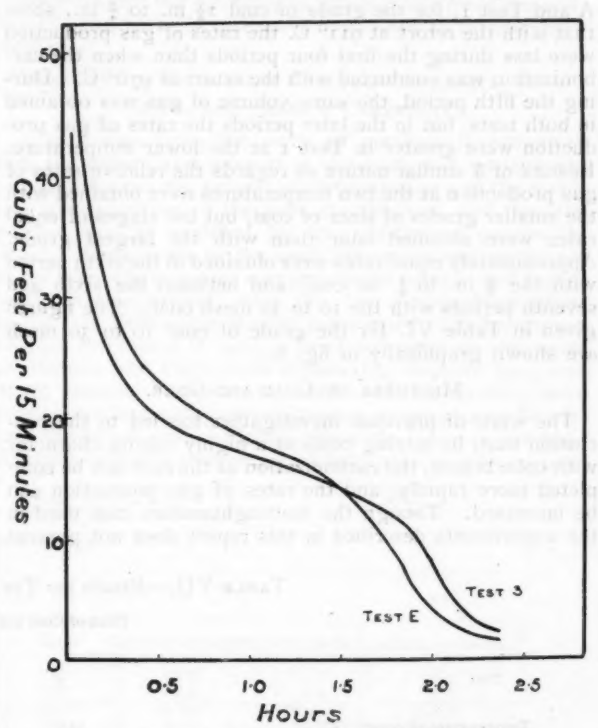

Fig. 8.—Rates of Gas Production, Influence of Temperature.

corresponding volumes obtained with the same sizes of coal in Tests A, C, and E with the retort at a temperature of 978° C. The results given in Table V. are represented graphically in figs. 5, 6, and 7, in which the volumes of gas made in cubic feet are plotted against the time of carbonization in hours. The curves denoted by broken lines are included to represent the differences in the volumes of gas produced under the two conditions of retort temperature, expressed as percentages of the larger volumes obtained at the higher temperature. The results in Table V. and the curves in figs. 5, 6, and 7 show the large reductions in the amounts of gas evolved at different stages, by lowering the temperature of the retort by about 60° C. From the broken-line curve in fig. 5, it may be seen that with 1¼ in. to ¾ in. coal, the volume of gas produced at the end of five minutes was 26 p.ct. less at 911° C. than at 976° C., and that this percentage difference gradually fell, as carbonization proceeded, to 8 p.ct. at the end of 2½ hours. With the ½ in. to ¼ in. coal (fig. 6) the percentage difference in the volumes of gas fell from 23 p.ct. to

6 p.ct., but with the 10 to 30 mesh coal, the difference rose from 17 p.ct. at the end of five minutes to 19 p.ct. after 10 minutes, and then decreased to 6 p.ct. at the end of 2½ hours.

The figures in Table VI. represent the differences in the volumes given in Table V. Table VI., therefore, shows the influence of retort temperature on the rates of gas production, expressed in volumes of gas evolved from 30 lbs. of coal during separate periods of fifteen minutes, at different stages of carbonization. The results given for Test A and Test 1, for the grade of coal 1¼ in. to ⅝ in., show that with the retort at 911° C. the rates of gas production were less during the first four periods than when the carbonization was conducted with the retort at 976° C. During the fifth period, the same volume of gas was obtained in both tests, but in the later periods the rates of gas production were greater in Test 1 at the lower temperature. Results of a similar nature as regards the relative rates of gas production at the two temperatures were obtained with the smaller grades of sizes of coal, but the stages of equal rates were attained later than with the largest grade. Approximately equal rates were obtained in the sixth period with the ½ in. to ¼ in. coal, and between the sixth and seventh periods with the 10 to 30 mesh coal. The figures given in Table VI. for the grade of coal 10 to 30 mesh are shown graphically in fig. 8.

TABLE VI.—*Gas Made During Each Fifteen Minutes' Period.*

(C.Ft. per 30 lbs. of Coal as Charged.)

Size of Coal	1¼ to ⅝ In.		½ to ¼ In.		10 to 30 Mesh.	
Test	A	1	C	2	E	3
Temp. of Retort, °C.	976	911	975	917	979	918
Period No.						
1	45·5	34·7	46·0	37·1	41·3	33·5
2	32·1	26·0	28·2	23·8	25·6	21·7
3	25·2	21·6	21·6	20·3	21·8	19·2
4	20·6	18·7	19·6	18·1	19·3	17·5
5	16·1	16·1	16·8	15·9	17·5	16·3
6	10·8	13·7	14·1	14·3	15·7	14·7
7	4·4	9·1	10·8	12·7	12·5	13·5
8	2·2	3·5	4·6	8·5	7·2	10·9
9	1·5	2·0	2·2	3·3	2·7	5·0
10	1·1	1·4	1·5	1·9	1·7	2·3

MIXTURES OF COAL AND COKE.

The work of previous investigators has led to the conclusion that, by mixing coals of a highly caking character with coke breeze, the carbonization of the coal can be completed more rapidly, and the rates of gas production can be increased. Though the Nottinghamshire coal used in the experiments described in this report does not possess a high caking index, it was considered that the study of the conditions affecting carbonization would not be complete without experiments designed to ascertain the influence of mixing coke with this coal. The results obtained might then afterwards be compared with those to be obtained when the study is extended to coals of higher caking powers.

For the purpose of determining the influence of blending the Nottinghamshire coal with coke and with other substances, the smallest grade of coal, 10 to 30 mesh, which could be satisfactorily carbonized alone was chosen. This grade of coal was mixed with the coke made from the same coal in the experiments previously carried out with the retort at a temperature of 980° C. The coke was first crushed and sieved, and the portion which passed through a sieve of 10 meshes to the inch, but remained on a 30 mesh sieve, was reserved for the experiments.

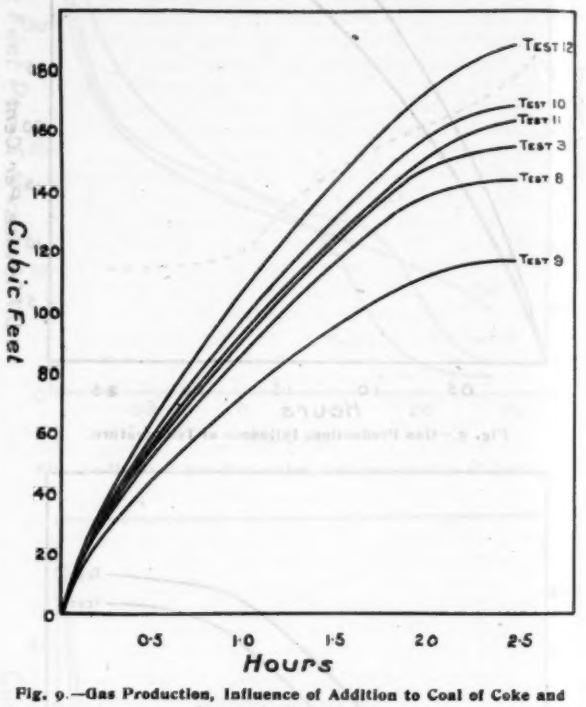

Fig. 9.—Gas Production, Influence of Addition to Coal of Coke and Inorganic Compounds.

The results obtained when the 10 to 30 mesh coal was carbonized alone and with mixtures of coal and coke are set out as Tests 3, 8, and 9 in Table VII. The figures

TABLE VII.—*Results per Ton of Material Charged into Retort.*

(Size of Coal used, 10 to 30 Mesh).

Test	3	8	9	10	11	12
Temperature of retort, °C.	918	925	910	921	917	912
Time of carbonization, hours	2·5	2·5	2·5	2·5	2·5	2·5
Substance added to coal	..	Coke	Coke	Calcium carbonate	Iron oxide	Sodium carbonate
Composition of mixture, percentages by weight:						
Coal	100	90	80	96·6	97·8	96·7
Added substance	..	10	20	3·4	2·2	3·3
Gas made per ton of charge, c.ft. (60° Fahr., 30 in.)	11,880	10,990	9,820	12,740	12,310	14,200
Composition of gas—volumes p.ct.:						
CO_2	3·5	3·2	4·1	6·4	4·4	6·2
C_mH_n	4·4	4·8	4·7	4·2	4·5	4·1
O_2	0·3	0·3	0·3	0·3	0·3	0·2
CO	11·7	11·4	11·2	12·8	12·0	14·8
H_2	51·2	51·7	51·3	49·8	51·5	50·2
C_nH_{2n+2}	27·5	27·5	27·0	24·6	25·8	22·9
N_2	1·4	1·1	1·4	1·9	1·5	1·6
	100·0	100·0	100·0	100·0	100·0	100·0
Calorific value of gas, B.Th.U. per c.ft. gross	593	599	589	563	570	536
" " " " " net	532	540	530	507	514	483
Thermal value of gas per ton of charge, therms gross	70·4	65·8	57·8	71·7	70·2	76·1
" " " " " " net	63·2	59·4	52·0	64·6	63·3	68·6
Specific gravity of gas (air = 1)	0·447	0·445	0·454	0·485	0·454	0·486
Coke (dry) in cwt. per ton of charge	13·0	13·7	14·2	13·0	13·2	12·9
Tar (dehydrated), gallons per ton of charge	7·6	6·0	4·7	6·6	6·1	5·4
Pitch from gas offtakes, lbs. per ton of charge	33	33	33	33	33	33
Ammonia liquor, gallons per ton of charge	23·4	22·8	21·5	21·8	22·5	18·1
Ammonium sulphate equivalent, per ton of charge, lbs.	25·1	24·8	23·2	32·7	25·6	26·5
Sulphuretted hydrogen, grains per 100 c.ft. gas	400	410	380	190	180	240

in this table represent the yields obtained per ton of material (coal or mixture of coal and coke) as charged into the retort. In Test 3 each charge consisted of 30 lbs. of 10 to 30 mesh coal. Each charge in Test 8 was made up of 27 lbs. of coal and 3 lbs. of coke, so that it consisted of 30 lbs. of mixture containing 90 p.ct. of coal and 10 p.ct. of coke; but in Test 9, owing to the greater volume occupied by the coke, the weight of charge was reduced to 27½ lbs. containing 22 lbs. of coal and 5½ lbs. of coke, or 80 p.ct. of coal and 20 p.ct. of coke. The amount of moisture in the coal as charged was 5·6 p.ct., and the quantity in the coke was 1·7 p.ct.

As was anticipated, the yields of gas in cubic feet per ton of material became less as the proportion of coke to coal was increased; and the thermal value of the gas made per ton fell from 70·4 therms gross with the coal alone to 57·8 therms with the mixture containing 20 p.ct. of coke. The compositions and calorific values of the gas made were approximately the same in all three tests. The yields of tar per ton of material decreased as the percentage of added coke was increased, but the amounts of coke increased from 13 cwt. to 14·2 cwt. per ton, *i.e.*, by amounts approximately equivalent to the coke added.

In order that a more satisfactory comparison might be made as regards yields of products, the figures per ton of material for Tests 3, 8, and 9 in Table VII. have been converted into amounts per ton of coal, Table VIII. From Table VIII. it may be seen that the coal-coke mixtures gave somewhat larger yields of gas and ammonia, and that the total thermal values of the gas made per ton of coal were a little greater. The amounts of tar obtained, however, in Tests 8 and 9 were lower than in Test 3.

Mixtures of Coal and Coke and Rates of Gas Production.

The total volume of gas made from each charge at the different stages of carbonization of the 10 to 30 mesh coal and the coal-coke mixtures in Tests 3, 8, and 9 are entered in Table IX. and reproduced graphically in fig. 9. In considering the figures given for these three tests, it must be remembered that the individual charges in the different tests did not contain the same weight of coal. The amount of coal per charge in Test 3 was 30 lbs., but in Tests 8 and 9 the weights were 27 lbs. and 22 lbs. respectively. The volumes of gas obtained at corresponding periods of carbonization were less with the coal-coke mixtures than with the coal alone.

The figures in Table IX. for Tests 3, 8, and 9 have been converted into volumes of gas corresponding with weights of charges containing 30 lbs. of coal, Table X. The figures given in Table X. show that, for the same weights of coal, larger volumes of gas were obtained from the coal-coke mixtures at all stages of carbonization. In considering these figures, however, account must be taken of the smaller weights of charge with mixtures containing coke, which could be placed in a retort of given size, owing to the greater volume occupied by coke as compared with the same weight of coal.

TABLE X.—*Gas Made in C.Ft. per 30 Lbs. of Coal.*

Test	3	8	9
Composition of mixture, p.ct by weight:			
Coal	100	90	80
Coke	..	10	20
Time of carbonization, hrs. mins.			
0 5	14·5	15·8	16·4
0 10	24·7	26·4	27·5
0 15	33·5	35·7	36·9
0 30	55·2	58·3	60·1
0 45	74·4	78·4	80·2
1 0	91·9	96·6	98·3
1 15	108·2	113·2	114·4
1 30	122·9	128·9	129·0
1 45	136·4	143·0	142·0
2 0	147·3	153·6	152·2
2 15	152·3	157·9	157·5
2 30	154·6	160·1	159·7

In general, the results obtained in Tests 3, 8, and 9 lead to the conclusion that the disadvantages more than counterbalance the advantages which result from the mixing of coke with the *particular coal* used in these experiments.

MIXTURES OF COAL WITH CALCIUM CARBONATE, IRON OXIDE, AND SODIUM CARBONATE.

It is known from the work of previous investigators that the nature and amount of the inorganic constituents of coal influence the process of carbonization and the qualities and quantities of the products obtained, and that the process can be modified by the addition of certain inorganic compounds to the coal before carbonization. It is not proposed to give a comprehensive summary of earlier work on this subject, since this has already been given in the Gas Fellowship Report presented to the Institution of Gas Engineers in 1925. Brief reference to the work of Marson and Cobb (Gas Fellowship Reports 1925 and 1926) should, however, be made. These investigators carried out laboratory carbonizations of samples of Sharlston Wallsend coal containing less than 1 p.ct. of ash. Samples of coke were prepared from this coal by carbon-

TABLE VIII.—*Results per Ton of Coal.*

(Size of Coal, 10 to 30 Mesh.)

Test	3	8	9	10	11	12
Substance added to coal	..	Coke	Coke	Calcium carbonate	Iron oxide	Sodium carbonate
Composition of mixture, p.ct. by weight:						
Coal	100	90	80	96·6	97·8	96·7
Added substance	..	10	20	3·4	2·2	3·3
Gas made per ton of coal, c.ft. (60° Fahr., 30 in.).	11,880	12,210	12,270	13,190	12,590	14,680
Thermal value of gas per ton of coal, therms gross	70·4	73·1	72·3	74·3	71·8	78·7
Thermal value of gas per ton of coal, therms net	63·2	65·9	65·0	66·9	64·7	70·9
Tar (dehydrated), gallons per ton of coal	7·6	6·7	5·9	6·8	6·2	5·6
Ammonia liquor, gallons per ton of coal	23·4	25·3	26·9	22·6	23·0	18·7
Ammonium sulphate equivalent, lbs. per ton of coal	25·1	27·6	29·0	33·9	26·2	27·4

TABLE IX. - *Gas Made in C.Ft. per Charge.*

Test	3	8	9	10	11	12
Substance added to coal	..	Coke	Coke	Calcium carbonate	Iron oxide	Sodium carbonate
Composition of mixture, p.ct. by weight—						
Coal	100	90	80	96·6	97·8	96·7
Added substance	..	10	20	3·4	2·2	3·3
Weight of charge, lbs.	30	30	27·5	31·1	30·7	31·0
Time of carbonization, hrs. mins.—						
0 5	14·5	14·2	12·0	15·5	14·7	15·6
0 10	24·7	23·8	20·2	26·3	25·0	27·1
0 15	33·5	32·1	27·1	35·5	33·7	37·2
0 30	55·2	52·5	44·1	58·8	56·0	63·6
0 45	74·4	70·6	58·8	79·0	75·4	86·6
1 0	91·9	86·9	72·1	97·5	93·2	107·3
1 15	108·2	101·9	83·9	114·5	109·5	125·9
1 30	122·9	116·0	94·6	130·3	124·4	142·9
1 45	136·4	128·7	104·2	144·7	138·2	158·2
2 0	147·3	138·2	111·6	157·4	150·4	171·9
2 15	152·3	142·1	115·5	165·1	159·4	182·8
2 30	154·6	144·1	117·1	168·4	163·2	188·3

ization before and after admixture with definite quantities of inorganic compounds. Iron oxide and calcium carbonate caused reductions in the amounts of nitrogen left in the coke prepared at 800° C.; but both these substances and sodium carbonate produced increases in the amounts of sulphur. The laboratory cokes were also examined as regards their activities towards steam at 1000° C., and towards carbon dioxide at 850° C. It was found that the cokes prepared by the carbonization of the coal after the addition of lime, iron oxide, or sodium carbonate were much more reactive than the coke made from the pure coal.

Though results of an interesting character were obtained in these experiments, it is not practicable in laboratory experiments on a small scale to determine the changes brought about during carbonization as regards rates of gas production, qualities of gas, and yields of the products gas, coke, tar, and ammonia. It was therefore decided to examine in the experimental plant the process of carbonization of the Nottinghamshire coal after admixture with calcium carbonate, iron oxide, and sodium carbonate. For this purpose, separate mixtures of the 10 to 30 mesh grade of coal were made with amounts of these three compounds (in powdered condition) equivalent to 2 parts by weight of the corresponding oxide to 98 parts of coal. These mixtures were then carbonized in the experimental plant; and the principal results obtained per ton of material—*i.e.*, coal mixture—are given as Tests, 10, 11, and 12 in Table VII. The conditions of carbonization employed were the same as those in Tests 1 to 9. The weights of individual charges of coal mixture were 31·07 lbs., 30·69 lbs., and 31·02 lbs. in Tests 10, 11, and 12 respectively. These weights of charge each contained 30 lbs. of coal. In calculating the weight of iron oxide required in Test 11, due allowance was made for the water of hydration (13 p.ct.) in the sample employed as determined by loss on ignition.

The results given in Table VII. show that larger yields of gas per ton of material were obtained in all three tests than in Test 3, in which the same grade of coal was carbonized alone. The calorific values of the gas produced, however, were lower than in Test 3; but the increased volumes were such that the thermal value of the gas made per ton was much greater with the sodium carbonate-coal, and a little greater with the calcium carbonate-coal, than with the coal alone. The thermal value of the gas made per ton in Test 11 with iron oxide was approximately the same as in Test 3. The compositions of the gases obtained with the mixture carbonized in Tests 10, 11, and 12 differed from that produced in Test 3, the most important differences being increased proportions of carbon dioxide and carbon monoxide, and reduced percentages of the methane hydrocarbons of the general formula C_nH_{2n+2}. The amounts of coke made were approximately the same as in Test 3; but the yields of tar were all lower, the smallest quantity being obtained in Test 12 with sodium carbonate. Smaller quantities of liquor were collected, especially in Test 12 with 18·1 gallons per ton of material as against 23·4 gallons in Test 3. The amounts of ammonia produced were a little greater in Tests 11 and 12 than in Test 3, but in Test 10 with calcium carbonate the yield of ammonia was increased by an amount equivalent to 7·6 lbs. of ammonium sulphate, from 25·1 lbs. to 32·7 lbs. per ton. The quantity of sulphuretted hydrogen in the crude gas was greatly reduced by the addition of the three compounds from 400 grains per 100 c.ft. in Test 3 to 190 grains, 180 grains, and 240 grains in Tests 10, 11, and 12 respectively. The increased yield of ammonia and the reduced quantity of sulphuretted hydrogen in the crude gas in Test 10 substantiate claims previously made as regards the addition of calcium carbonate to the coal to be carbonized.

The quantities of products given in Table VII. for Tests 10, 11, and 12 are expressed in Table VIII. as yields per ton of coal contained in the mixtures. The largest increase in the volume of gas per ton of coal resulted from the addition of sodium carbonate, which gave 14,680 c.ft., or 24 p.ct. more than the volume of 11,880 c.ft. produced from the coal only. The increased gas volume with calcium carbonate was 1310 c.ft., or 11 p.ct., and with iron oxide the extra volume was 710 c.ft., or 6 p.ct. The gross thermal value of the gas made per ton of coal in Test 12 with sodium carbonate was 78·7 therms, or 12 p.ct. more than the 70·4 therms obtained in Test 3. The thermal values of the gas produced in Tests 10 and 11 represent increases of 5·5 p.ct. and 2 p.ct. respectively. The yield of ammonia in Test 10 with calcium carbonate was equivalent to 33·9 lbs. of ammonium sulphate, or 35 p.ct. more than the 25·1 lbs. obtained in Test 3.

The volumes, in c.ft., of the constituents of the gas made per ton of coal in Test 3 with the 10 to 30 mesh coal, and in Tests 10, 11, and 12, in which calcium carbonate, iron oxide, and sodium carbonate were added, have been calculated from the compositions (Table VII.) and the total volumes (Table VIII.); and the figures obtained appear in Table XI. From these figures, the volumes of the constituent gases in excess of the volumes in Test 3 have been obtained by difference. The difference figures show that the increases in the volumes of gas produced consisted mainly of hydrogen, carbon dioxide, and carbon monoxide.

The substances added to the coal in Tests 10 and 12 each contained combined carbon dioxide, which may to some extent have been liberated during the process of carbonization: and the carbon dioxide liberated in this manner may have been partially reduced to carbon monoxide. This explanation, however, cannot account for the whole of the gaseous oxides of carbon produced in Tests 10 and 12 in excess of the volume obtained in Test 3. For example, the quantity of calcium carbonate added in Test 10 could only give rise, if complete decomposition occurred, to oxides of carbon equivalent to about 300 c.ft. of carbon dioxide, as against the additional volumes of 428 c.ft. of carbon dioxide and 298 c.ft. of carbon monoxide obtained. Similarly, the sodium carbonate added in Test 12 might produce a maximum quantity of oxides of carbon equivalent to about 270 c.ft. of carbon dioxide, as compared with 494 c.ft. of carbon dioxide and 782 c.ft. of carbon monoxide actually obtained. The maximum quantity of oxides of carbon which could result from the complete reduction of the iron oxide added in Test 11, would be equivalent to 160 c.ft. of carbon dioxide, whereas the additional oxides of carbon actually obtained were equivalent to 198 c.ft. of carbon dioxide; and it is almost certain that complete reduction of the oxide of iron did not occur. Further, the simple decomposition of the com-

TABLE XI.—*Volumes of Constituent Gases in C.Ft. per Ton of Coal.*

Test	3	10		11		12	
Substance added to coal	..	Calcium carbonate		Iron oxide		Sodium carbonate	
Composition of mixture, p.ct. by weight:							
Coal	100	96·6		97·8		96·7	
Added substance	..	3·4		2·2		3·3	
	Volumes per Ton of Coal.	Volumes per Ton of Coal.	Excess Over Test 3.	Volumes per Ton of Coal.	Excess Over Test 3.	Volumes per Ton of Coal.	Excess Over Test 3.
Constituent gases, volumes in c.ft.:							
CO_2	416	844	428	554	138	910	494
C_mH_n	523	554	31	566	43	602	79
O_2	36	40	4	38	2	29	− 7
CO	1,390	1,688	298	1,511	121	2,173	783
H_2	6,082	6,569	487	6,484	402	7,369	1287
C_nH_{2n+2}	3,267	3,245	− 22	3,248	− 19	3,362	95
N_2	166	250	84	189	23	235	69
	11,880	13,190	1310	12,590	710	14,680	2800

pounds added to the coal could not account for the large increases in the volumes of gaseous hydrogen produced.

It thus seems that the added compounds influenced the progress of the decomposition of the coal substance during carbonization. The exact nature of the changes and the mechanism by which they were brought about cannot be explained at this stage of the investigation. It should, however, be observed from Table VIII. that the amounts of tar produced per ton of coal were less in Tests 10, 11, and 12 than in Test 3; and this fact would account for some of the additional gaseous hydrogen, carbon dioxide, and carbon monoxide. Further, the volumes of liquor collected were rather less in Tests 10 and 11 than in Test 3, and much less in Test 12 with 18·7 gallons in place of 23·4 gallons per ton of coal. The diminution of 4·7 gallons of liquor in Test 12, which resulted from the addition of sodium carbonate, represents an amount of water which, on interaction with carbon, would give rise to approximately 1000 c.ft. of hydrogen and the equivalent in oxides of carbon of 500 c.ft. The observed reduction of 0·4 gallons of liquor in Test 11 should be corrected by the addition of 0·7 gallon which would result from the removal of water of hydration contained in the added iron oxide, making a true diminution of 1·1 gallons. This amount of water corresponds with about 230 c.ft. of hydrogen.

It does seem probable that some of the water ordinarily collected as liquor in the carbonization of the coal alone was converted into water gas as a result of the addition of the compounds employed in Tests 10, 11, and 12. The cokes produced in these three tests, when heated to 1000° C., certainly reacted with steam more readily than the coke obtained in Test 3 with coal alone. It is likely that during the distillation of the coal mixture in the middle of the charge, some of the water vapour produced by the decomposition of the coal substance travelled through coke which had already been produced and had attained a high temperature, and that this water vapour was then partly converted into water gas by interaction with the coke rendered more reactive towards steam as a result of the added compounds.

Added Compounds and Rates of Gas Production.

The total volumes of gas which had been evolved as carbonization of each charge progressed in Test 3 with the 10 to 30 mesh coal, and in Tests 10, 11, and 12 with mixtures of this coal with calcium carbonate, iron oxide, and sodium carbonate are given in Table IX. The volumes given in this table do not include the carbon dioxide removed in the purifiers through which a solution of caustic soda was circulated; the figures, however, are comparable. The weight of each charge in Test 3 was 30 lbs., and in each of the Tests 10, 11, and 12 the weight of mixture employed was such that each charge contained 30 lbs. of coal. The results obtained, which are reproduced graphically in fig. 9, show that at all stages of carbonization more gas had been evolved in the tests with the added compounds than with the coal alone. Comparing the figures for Tests 10, 11, and 12, it will be observed that at all stages of carbonization the largest quantity of gas had been obtained from the coal-sodium carbonate mixture, and the smallest quantity from the coal-iron oxide mixture; the yields of gas resulting from the addition of calcium carbonate being intermediate.

The volumes of gas produced from individual charges during separate periods of fifteen minutes as carbonization progressed are given in Table XII. The figures in this table show that the highest rates of gas production in all periods were obtained in Test 12 as a result of the addition of sodium carbonate, and that the lowest rates were obtained in Test 3 with the coal alone. The rates of gas production which resulted from the addition of calcium carbonate, Test 10, were greater than those in Test 11 with iron oxide for the first eight periods of fifteen minutes—*i.e.*, during the first two hours—but in the last half-hour gas was evolved more rapidly in Test 11.

Reviewing the figures given in Tables VII., VIII., IX., XI., and XII. for Tests 3, 10, 11, and 12, it has been found that the addition of calcium carbonate, iron oxide, and sodium carbonate separately to the Nottinghamshire coal carbonized at high temperature produced larger volumes of gas of lower calorific value per cubic foot, higher rates of gas production, and greater thermal yields of gas per ton of coal, especially as a result of the addition of sodium carbonate. The amounts of sulphuretted hydrogen in the crude gas were considerably reduced. The yields of tar were lower with all three additions; but the quantities of ammonia obtained were greater, especially with calcium carbonate, which produced an increase in the ammonia yield of approximately 35 p.ct. In considering these results, it must be remembered that the grade of coal employed, 10 to 30 mesh, enabled intimate mixture with the added substance, and that the carbonizations were conducted in a retort made of cronite alloy. Sodium carbonate would have a detrimental effect on retorts of fireclay or silica.

TABLE XII.—*Gas Made During Each Period of Fifteen Minutes.*

(C.Ft. per Charge containing 30 lbs. of Coal.)

Test	3	10	11	12
Substance added to coal	..	Calcium carbonate	Iron oxide	Sodium carbonate
Composition of mixture, p.ct. by weight—				
Coal	100	96·6	97·8	96·7
Added substance	..	3·4	2·2	3·3
Period No. 1	33·5	35·5	33·7	37·2
2	21·7	23·3	22·3	26·4
3	19·2	20·2	19·4	23·0
4	17·5	18·5	17·8	20·7
5	16·3	17·0	16·3	18·6
6	14·7	15·8	14·9	17·0
7	13·5	14·4	13·8	15·3
8	10·9	12·7	12·2	13·7
9	5·0	7·7	9·0	10·9
10	2·3	3·3	3·8	5·5

ANALYSES OF COAL, COKE, TAR, AND PITCH.

The results of proximate and ultimate analyses of the several grades of sizes of coal used in the tests are given in Table XIII., in which the gross calorific values as determined in a Mahler bomb calorimeter are also included. In the preparation of the different grades of coal, precautions were taken to ensure that each grade would be, as nearly as possible, of the same composition. From the ultimate analyses, it may be seen that the differences in composition of the grades prepared were small. The percentage of ash was 4·1 in each of the sizes 1¼ in. to ⅜ in., ½ in. to ¼ in., and 10 to 30 mesh; and the amount in the coal below 30 mesh was only 0·4 p.ct. greater. The percentages of carbon in the three largest grades ranged between 78·7 and 79; and in the smallest grade of coal the amount of carbon was 78·4 p.ct. The differences in composition, therefore, were little more than might be explained by experimental errors of sampling and analysis.

TABLE XIII.—*Analyses of Coal (Dried Samples).*

Size of Coal	1¼ to ⅜ In.	½ to ¼ In.	10 to 30 Mesh.	Through 30 Mesh
Test	1, 4, and 7.	2, 5, and 7.	4 to 12.	7.
Proximate analysis:				
Volatile matter	37·6	38·0	37·9	36·8
Fixed carbon	58·3	57·9	58·0	58·7
Ash	4·1	4·1	4·1	4·5
	100·0	100·0	100·0	100·0
Ultimate analysis:				
Ash	4·1	4·1	4·1	4·5
Carbon	78·8	79·0	78·7	78·4
Hydrogen	4·8	4·9	4·8	4·8
Sulphur	1·3	1·3	1·3	1·4
Nitrogen	1·8	1·7	1·7	1·7
Oxygen (by difference)	9·2	9·0	9·4	9·2
	100·0	100·0	100·0	100·0
Calorific value (gross) B.Th.U. per lb.	13,900	13,900	13,900	13,800

The compositions of the coke used for mixing with the 10 to 30 mesh coal in Tests 8 and 9, and of the cokes produced in all tests, are given in Table XIV. The coke used for mixing with coal contained 9·8 p.ct. of ash. The compositions of the cokes obtained in Tests 1 to 7, in which different sizes of the coal were carbonized separately, and after admixture with one another, were approximately the same; but owing to the admixture of coke containing

TABLE XIV.—*Analyses of Coke (Dried Samples).*

Test	Blended with Coal 8 and 9.	1	2	3	4	5	6	7	8	9	10	11	12
Proximate analysis—													
Volatile matter	3·5	1·9	3·2	2·4	3·0	3·1	2·1	2·1	2·6	2·2	4·8	3·1	3·8
Fixed carbon	86·7	92·0	90·8	91·6	91·0	90·9	91·9	91·8	90·8	90·7	83·8	88·4	84·7
Ash	9·8	6·1	6·0	6·0	6·0	6·0	6·0	6·1	6·6	7·1	11·4	8·5	11·5
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Ultimate analysis—													
Ash	9·8	6·1	6·0	6·0	6·0	6·0	6·0	6·1	6·6	7·1	11·4	8·5	11·5
Carbon	85·6	89·8	89·2	89·4	88·6	89·1	89·0	89·3	88·5	88·2	83·5	86·8	84·3
Hydrogen	0·5	0·7	0·7	0·8	0·8	0·8	0·7	0·8	0·8	0·6	0·8	0·8	0·9
Sulphur	1·5	1·2	1·2	1·2	1·2	1·2	1·2	1·2	1·2	1·2	1·7	1·6	1·6
Nitrogen	1·6	1·8	1·7	1·7	1·8	1·7	1·8	1·7	1·7	1·6	1·4	1·4	1·7
Oxygen (by diff.)	1·0	0·4	1·2	0·9	1·6	1·2	1·3	0·9	1·2	1·3	1·2	0·9	0·0
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Calorific value (gross) B.Th.U. per lb.	12,600	13,500	13,300	13,400	13,300	13,300	13,400	13,300	13,400	13,100	12,700	12,900	12,600

TABLE XV.—*Analysis of Tar (Dehydrated Samples).*

Test	1	2	3	4	5	6	7	8	9	10	11	12
Ultimate analysis:												
Carbon	87·6	87·9	88·0	88·6	88·6	88·2	88·5	87·7	89·5	88·8	88·8	88·7
Hydrogen	5·4	5·5	5·5	5·4	5·4	5·4	5·3	5·3	5·5	5·5	5·5	5·6
Sulphur	1·1	1·1	1·1	1·1	1·1	1·1	1·1	1·1	1·1	0·9	0·9	0·9
Nitrogen	1·2	1·2	1·2	1·2	1·1	1·1	1·2	1·2	1·1	1·0	1·1	1·1
Oxygen and ash (difference)	4·7	4·3	4·2	3·7	3·8	4·2	3·9	4·7	2·8	3·8	3·7	3·7
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Calorific value (gross), B.Th.U. per lb.	15,900	15,900	15,900	16,100	16,100	15,500	15,900	15,900	16,100	16,000	16,000	16,000

TABLE XVI.—*Distillation Tests of Dehydrated Tar.*

Test	1	2	3	4	5	6	7	8	9	10	11	12
Specific gravity	1·17	1·18	1·18	1·18	1·18	1·16	1·19	1·17	1·17	1·17	1·17	1·16
Volumes p.ct.—												
Below 170° C.	5·6	3·8	6·8	6·5	5·0	9·1	6·5	5·6	5·0	5·4	5·3	6·0
170° to 270° C.	32·8	27·1	27·5	29·9	29·8	28·3	28·9	31·2	33·3	25·6	30·3	31·1
Pitch	60·6	68·1	64·2	63·1	64·6	61·4	64·6	61·7	60·3	66·1	64·4	62·4
	99·0	99·0	98·5	99·5	99·4	98·8	100·0	98·5	98·6	97·1	100·0	99·5
Yield of pitch, weight p.ct.	66·3	73·9	70·0	69·3	70·3	68·0	70·5	68·0	66·4	72·1	69·7	68·0

TABLE XVII.—*Weight Balances, Lbs. per Ton of Material Charged into Retort.*

Test	1	2	3	4	5	6	7	8	9	10	11	12
Coal	2240	2240	2240	2240	2240	2240	2240	2016	1792	2163	2190	2166
Added substance	..	..	..	..	..	..	..	224	448	77	50	74
	2240	2240	2240	2240	2240	2240	2240	2240	2240	2240	2240	2240
Gas	390	410	404	408	419	408	411	372	339	470	425	525
Coke	1422	1456	1456	1456	1467	1445	1456	1534	1590	1456	1478	1445
Tar	127	101	83	81	85	97	82	70	55	77	70	63
Pitch	33	33	33	33	33	33	33	33	33	33	33	33
Liquor	253	237	239	246	244	245	245	233	220	225	230	186
Sulphuretted hydrogen	7	7	6	8	8	7	7	6	5	4	3	5
	2232	2244	2221	2232	2256	2235	2231	2248	2242	2265	2239	2257

9·8 p.ct. of ash with the coal carbonized in Tests 8 and 9, the cokes produced in these two tests contained larger quantities of ash than those obtained in Tests 1 to 7. The addition of calcium carbonate, iron oxide, and sodium carbonate to the coal carbonized in Tests 10, 11, and 12 respectively resulted in larger proportions of ash in the cokes produced in these tests than in Test 3, in which the same grade of coal was carbonized without addition. The amount of sulphur in the calcium carbonate coke, Test 10, was 1·7 p.ct., or 0·5 p.ct. greater than in Test 3; and the amount of sulphur in the iron oxide coke and the sodium carbonate coke was 1·6 p.ct. The retention of greater amounts of sulphur in the cokes which resulted from the additions of the three compounds to the coal in Tests 10, 11, and 12 was accompanied by reductions in the quantities of sulphuretted hydrogen in the crude gas (*vide* Table VII.). Calcium carbonate and iron oxide caused a diminution in the quantity of nitrogen left in the coke from 1·7 p.ct. in Test 3 to 1·4 p.ct. in Tests 10 and 11; but the addition of sodium carbonate in Test 12 did not affect the nitrogen content of the coke. In general, the observed influences of the compounds added in the last three tests on the sulphur and nitrogen contents of the cokes confirm the results previously obtained in the laboratory experiments, described in the Gas Research Fellowship Report (1926), to which reference has already been made.

The results of ultimate analyses and determinations of the calorific values of samples of dehydrated tar obtained during the tests are shown in Table XV.; and the results of distillation tests of the dehydrated tars are set out in Table XVI. The ultimate analyses and calorific values do not exhibit any large differences; but it should be noted that the percentages of sulphur in the tars produced in Tests 10, 11, and 12, in which calcium carbonate, iron oxide, and sodium carbonate were added to the coal, were

TABLE XVIII.—*Weight Balances, P.Ct.*

Test	1	2	3	4	5	6	7	8	9	10	11	12
Coal	100·0	100·0	100·0	100·0	100·0	100·0	100·0	90·0	80·0	96·6	97·8	96·7
Added substance	..	..	..	..	..	..	..	10·0	20·0	3·4	2·2	3·3
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Gas	17·4	18·3	18·0	18·2	18·7	18·2	18·4	16·6	15·1	21·0	19·0	23·4
Coke	63·5	65·0	65·0	65·0	65·5	64·5	65·0	68·5	71·0	65·0	66·0	64·5
Tar	5·7	4·5	3·7	3·6	3·8	4·3	3·7	3·1	2·5	3·4	3·1	2·8
Pitch	1·5	1·5	1·5	1·5	1·5	1·5	1·5	1·5	1·5	1·5	1·5	1·5
Liquor	11·3	10 6	10·7	11·0	10·9	10·9	10·9	10·4	9·8	10·0	10·3	8·3
Sulphuretted hydrogen	0·3	0·3	0·3	0·4	0·4	0·3	0·3	0·3	0·2	0·2	0·1	0·2
	99·7	100·2	99·2	99·7	100·8	99·7	99·8	100·4	100·1	101·1	100·0	100·7

TABLE XIX.—*Carbon Balances, Lbs. per 100 Lbs. of Material Charged into Retort.*

Test	1	2	3	4	5	6	7	8	9	10	11	12
Coal	74·6	74·4	74·1	74·3	74·3	74·3	74·6	66·8	59·4	71·8	72·7	71·8
Added substance	..	..	..	..	..	..	..	8·4	16·8	0·4	*Nil*	0·4
	74·6	74·4	74·1	74·3	74·3	74·3	74·6	75·2	76·2	72·2	72·7	72·2
Gas	9·0	9·6	9·4	9·7	9·9	9·8	9·7	8·9	7·9	10·2	9·6	11·3
Coke	57·0	58·0	58·1	57·6	58·4	57·4	58 1	60·6	62·6	54·3	57·3	54·4
Tar	5·0	4 0	3·3	3·2	3·4	3·8	3·2	2·8	2·2	3·1	2·8	2·5
Pitch	1·1	1·1	1·1	1·1	1·1	1·1	1·1	1·1	1·1	1·1	1·1	1·1
Liquor	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·7	0 5	0·7
	72 5	73·1	72 3	72·0	73·2	72·5	72·5	73·8	74·2	69·4	71·3	70·0

TABLE XX.—*Carbon Balances, P.Ct.*

Test	1	2	3	4	5	6	7	8	9	10	11	12
Coal	100·0	100·0	100·0	100·0	100·0	100·0	100·0	88·8	78·0	99·4	100·0	99·4
Added substance	..	..	..	..	..	..	..	11·2	22·0	0·6	..	0·6
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Gas	12·1	12·9	12·7	13·1	13·3	13·2	13·0	11·8	10·4	14·1	13·2	15·6
Coke	76·4	77·9	78·4	77·5	78·6	77·3	77·9	80·6	82·1	75·2	78·8	75·4
Tar	6·7	5·4	4·5	4·3	4·6	5·1	4·3	3·7	2·9	4·3	3·9	3·5
Pitch	1·5	1·5	1·5	1·5	1·5	1·5	1·5	1·5	1·4	1·5	1·5	1·5
Liquor	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5	1·0	0·7	1·0
	97·2	98·2	97·6	96·9	98·5	97·6	97·2	98·1	97·3	96·1	98·1	97·0

TABLE XXI.—*Heat Balances, Therms per Ton of Material Charged into Retort.*

Test	1	2	3	4	5	6	7	8	9	10	11	12
Coal	294·7	293·3	293 3	293·9	293·3	293·6	294·6	264·5	235·2	283·9	287·4	284·3
Added substance	..	..	..	..	..	..	..	27·7	55·5	*Nil*	*Nil*	*Nil*
	294·7	293·3	293·3	293·9	293·3	293·6	294·6	292·2	290·7	283·9	287·4	284·3
Gas	67·3	71·1	70·4	70·9	71·9	72·0	71·1	65·8	57·8	71·7	70·2	76·1
Coke	192·0	193·6	195·1	193·6	195·2	193·6	193·6	205·5	208·3	184·9	190·6	182·1
Tar	20·2	16·1	13·2	13·0	13·7	15·4	13·0	11·1	8·9	12·3	11·2	10·1
Pitch	4·4	4·4	4·4	4·4	4·4	4·4	4·4	4·4	4·4	4·4	4·4	4·4
Sulphuretted hydrogen and ammonia	1·1	1·2	1·1	1·1	1·2	1·2	1·1	1·1	1·0	1·0	0·8	1·1
	285·0	286·4	284·2	283·0	286·4	286·6	283·2	287·9	280·4	274·3	277·2	273·8

less than in the tars obtained in any of the other tests. The smallest percentage of nitrogen was contained in the tar from Test 10, in which calcium carbonate was added to the coal; and this test gave the largest yield of ammonia (*vide* Table VIII.).

The percentage composition of an average sample of the pitch removed from the gas offtakes of the retort during the tests was as follows: Carbon 77·8, hydrogen 4·6, sulphur 0·9, nitrogen 4·1, ash 2·9, oxygen by difference 9·7. The calculated gross calorific value of pitch of this composition is approximately 13,400 B.Th.U. per lb. The high percentage of nitrogen probably resulted from the presence of ammonium chloride, as was proved in the pitch collected during the tests described in the Sixteenth Report.

WEIGHT BALANCES.

From the figures given in Tables I. and VII. to represent the yields of the products per ton of material charged into the retort, the weight balances set out in Table XVII. have been constructed, with the object of ascertaining the accuracy with which the tests were carried out. In Table XVIII. the weight of material charged into the retort in each test is taken as 100, and the weights of the products are in proportion; so that the figures represent the weights of the products as percentages of the weight of material carbonized.

CARBON BALANCES.

Carbon balances for the amounts of this element in the coal and added coke or other substance and in the products of carbonization are given in Table XIX., in which the figures represent the amounts of carbon as percentages by weight of the material charged into the retort. In Table XX. the figures in Table XIX. have been brought up in such proportion that the amount of carbon in the material carbonized is represented as 100, so that the items in Table XX. show the distribution of carbon in the products as percentages of the carbon contained in the coal or coal mixture charged into the retort. The figures given for the amounts of carbon in the liquors collected have been obtained from analyses of the liquors for carbonate only;

TABLE XXII.—*Heat Balances, P.Ct.*

Test	1	2	3	4	5	6	7	8	9	10	11	12
Coal	100·0	100·0	100·0	100·0	100·0	100·0	100·0	90·5	80 9	100 0	100·0	100·0
Added substance	..	..	..	..	..	..	..	9·5	19·1	*Nil*	*Nil*	*Nil*
	100·0	100·0	100·0	100·0	100 0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Gas	22·8	24·2	24·0	24·1	24·5	24·5	24·1	22·5	19·9	25·2	24·4	26·8
Coke	65·1	66·0	66·5	65·9	66·5	66·0	65·7	70·3	71·6	65·2	66·4	64·0
Tar	6 9	5·5	4·5	4·4	4·7	5·2	4·4	3·8	3·1	4·3	3·9	3·6
Pitch	1·5	1·5	1·5	1·5	1·5	1·5	1·5	1·5	1·5	1·5	1·5	1·5
Sulphuretted hydrogen and ammonia	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·3	0·4
	96·7	97·6	96·9	96·3	97·6	97·6	96·1	98·5	96·5	96 6	96·5	96·3

they do not include carbon present in other forms, such as pyridine, phenol, cyanide, and thiocyanate. The amounts of carbon present in the liquors but not included in the tables, however, would be small—probably less than 0·5 p.ct. of the carbon contained in the material charged into the retort.

THERMAL BALANCES.

The thermal balances in Table XXI. have been constructed from the gross calorific values of the coal and coke used in the tests and of the products of distillation. The figures show the distribution of heat energy in therms per ton of material submitted to carbonization. In Table XXII. the heat values of the products are shown as percentages of the heat values of the coal or mixture charged into the retort. The calorific values of any combustible compounds which may have been present in the liquor, apart from ammonia, have not been included; but this omission should be less than the probable experimental errors involved in the determinations of the heat values included in the table.

EXAMINATION OF COKE.—PHYSICAL STRUCTURE, REACTIVITY TOWARDS STEAM AND CARBON DIOXIDE, IGNITION TEMPERATURE.

Samples of the cokes produced during the tests in which graded sizes of the Nottinghamshire coal were carbonized in the experimental plant with the cronite retort at approximately 980° C., were examined as regards physical structure by means of low and high power lenses. The methods of examination were described in the Sixteenth Report, in which photographs of typical lumps of coke and of plane polished sections prepared in plaster were given. From the macro- and micro-examination of the polished sections it was found that the coke produced from the 10 to 30 mesh coal was more uniform in structure than the coke from the larger grades of coal. Further, in the coke from the 10 to 30 mesh coal the walls of the larger cells contained a greater number of very small pores.

During the past year the cokes prepared in the tests described in the Sixteenth Report have been examined as regards reactivity towards steam at 1000° C., in a laboratory apparatus under standard conditions. Modifications of the same apparatus have also been employed for the determination of "ignition temperatures" in oxygen and for the measurement of the comparative reactivities of the cokes towards carbon dioxide at definite temperatures. The cokes produced in the twelve tests described in this Eighteenth Report are also under examination as regards physical structure, reactivity, and "ignition temperature;" but it is considered preferable to defer a detailed description of the apparatus and results until the examination has been completed. Meanwhile, some of the results already obtained might be mentioned.

The "ignition temperatures" of the cokes prepared from Nottinghamshire coal in the experimental plant with the cronite retort at about 980° C. were determined in an electric furnace with a rate of heating-up of the coke of 10° C. per minute, and a rate of flow of oxygen of 10 litres per hour. For these determinations the cokes were crushed and graded $\frac{1}{8}$ in. to $\frac{3}{8}$ in. The figures obtained did not differ greatly from one another, and averaged approximately 420° C. This result is given in Table A, together with the "ignition temperatures," determined under exactly the same conditions, of coke prepared from Sharlston Wallsend coal alone and after admixture with iron oxide, lime, and sodium carbonate.

The "ignition temperature" of coke prepared in a laboratory apparatus at 800° C. from Sharlston Wallsend coal was approximately 440° C., or about 20° C. higher than the "ignition temperature" of the coke from the Nottinghamshire coal carbonized in the experimental plant at 980° C. The addition of iron oxide and lime to Sharlston Wallsend coal, in the proportion of 5 p.ct. of the weight of the coal, resulted in cokes with the lower "ignition temperatures" of 345° C. and 400° C.; but the addition of sodium carbonate produced a coke with a much higher "ignition temperature"—560° C. to 600° C.

TABLE A.—"*Ignition Temperatures*" *in Oxygen.*

Coal Carbonized.	Description of Coke.	Ignition Temp., °C.
Nottinghamshire	Experimental plant, 980° C.	420
Sharlston Wallsend	"Pure" coke, 800° C.	432—450
,, ,,	5 p.ct. CaO coke, 800° C.	388—408
,, ,,	5 p.ct. Fe_2O_3 ,, ,,	338—352
,, ,,	5 p.ct. Na_2CO_3 ,, ,,	560—600

The reactivities towards steam of the cokes prepared in the tests described in the Sixteenth Report were determined at 1000° C., with a rate of flow of steam of 10 litres per hour. The percentages of steam decomposed by these eight cokes were approximately the same, and averaged 77 p.ct. This figure is given in Table B, which also includes results taken from the Gas Research Fellowship Report (1926) for cokes made at 800° C. from Sharlston Wallsend coal, and the results obtained with cokes produced from Nottinghamshire coal at about 915° C. in the tests described in this report. The research staff are indebted to Prof. J. W. Cobb and Mr. J. A. Sutcliffe for determinations of the amounts of steam decomposed at 1000° C. by the cokes produced in Tests 3, 10, 11, and 12. These four cokes were examined to ascertain whether the influences of the added compounds were similar to those observed in laboratory carbonizations of Sharlston Wallsend coal.

The coke obtained by the carbonization of the Nottinghamshire coal in the experimental plant with the retort at 918° C. was more reactive towards steam at 1000° C. than coke prepared from the same coal at 980° C. The reduction of approximately 60° C. in the temperature of the retort caused an increase in the percentage of steam decomposed of 8 p.ct., from 77 p.ct. to 85 p.ct. The addition of calcium carbonate, iron oxide, and sodium carbonate to the Nottinghamshire coal before carbonization with the retort at about 915° C. resulted in considerable increases in the reactivities of the cokes towards steam. Sodium carbonate produced the greatest increase, and calcium carbonate the smallest increase, in reactivity; the iron oxide coke being intermediate. The effects of the added compounds follow the same order as the changes in reactivity observed with the cokes obtained from Sharlston Wallsend coal at 800° C.

TABLE B.—*Reactivity of Cokes with Steam at* 1000° *C.*

Coal Carbonized.	Description of Coke.	Steam Decomposed, P.Ct.
Nottinghamshire	16th Report, Tests A to H, 980° C.	77
,,	18th ,, Test 3, 918° C.	85
,,	,, ,, Test 10, $CaCO_3$ coke	92
,,	,, ,, Test 11, Fe_2O_3 coke	95
,,	,, ,, Test 12, Na_2CO_3 coke	98
Sharlston Wallsend	"Pure" coke, 800° C.	61
,, ,,	5 p.ct. CaO coke, 800° C.	82
,, ,,	5 p.ct. Fe_2O_3 ,, ,,	91
,, ,,	5 p.ct. Na_2CO_3 ,, ,,	98

A consideration of the figures given in Tables A and B for the three cokes prepared at 800° C. by the carboniza-

tion of Sharlston Wallsend coal alone and with added iron oxide and lime shows that the "pure" coke, which was the least reactive towards steam, possessed the highest "ignition temperature," and that the iron oxide coke, which was most reactive towards steam, gave the lowest "ignition temperature." It is somewhat surprising, however, to find that the sodium carbonate coke which was even more reactive towards steam than the iron oxide coke, gave an "ignition temperature" higher than that obtained with any other coke. It would appear from the results that no definite relationship between the reactivity of coke towards steam at 1000° C. and "ignition temperature" has been established.

Prof. J. W. COBB, in introducing the report, said: This report deals with the second part of the work carried out during the past twelve months by the Gas Research Sub-Committee. The reason for the choice of subject-matter, I think, might be taken, partly at any rate, to be contained in the suggestion put forward once or twice already this afternoon—that thermal efficiency is not the whole of the story when we are dealing with the performance of carbonization plants; that other factors, such as rapid output tending to lessen labour costs, and simplified processes, also come into play; and that, in order to arrive at full information for the carbonization industries, it is advisable to be as fully conversant as is possible with the properties of coal from that point of view. A beginning in this direction was made last year, when reports were presented upon the influence of the sizing of coal; and we have already had interesting testimony to the fact that these results excite interest, and have been found useful in practice. This sort of investigation has been carried on this year by a further study of the influence of different sizes of coal and of admixture, and of the effects produced by the addition of various inorganic compounds such as are present in coal ash. As regards admixture, I think I will leave that part of it to be dealt with by Dr. Parker, and merely allude to one important point which I think should never be lost sight of in the interpretation of such figures as are set out in the report. This point is of particular importance when one considers possible processes for the preparation of a solid smokeless fuel, and means likely to prove the most economical for carrying out a partial carbonization. Low-temperature carbonization suggests one way in which this may be done. But it is possible that methods more economical commercially may be forthcoming such as incomplete high-temperature carbonization carried out rapidly; and the data in the tables to which I have referred will be interesting, because comparisons can be made not only between the final results of the carbonization of two different kinds of materials—which sometimes disclose small differences—but between different stages while the carbonization is in progress, when very much greater differences between the results obtained in one experiment and in another are apt to disclose themselves.

Now as to the addition of inorganic compounds. In the Gas Research Fellowship results returned last year and the year before, it was pointed out that by the addition of various constituents, particularly sodium carbonate, oxide of iron, and lime, remarkable differences were made to the results obtained by the carbonization of coal on the laboratory scale, and that differences even more remarkable disclosed themselves when the resulting cokes were tested as to their rates of gasification in steam or CO_2, and as to the production of water gas from them. The cokes obtained from coals to which sodium carbonate and oxide of iron had been added were closer in texture, and quite different from those made from the pure coal without admixture in the laboratory; but it was obvious from some experiments that we made that this sort of difference was of a rather elusive character. And if one considers what is the actual occurrence in the coal which is responsible for the difference in porosity and general external structure of the coke, one must come to the conclusion that it is due to the difference in the rate of liberation of gaseous volatile matter during the stage when the coal is of a plastic character. Such differences are likely to exaggerate themselves in such rapid carbonization as is usually effected in the laboratory, and such conditions are likely to smooth themselves out when the carbonization occurs over a longer period of time. For that reason the Corbet Woodall carbonization plant was suitably modified, and experiments were made by Dr. Parker and his assistants on coals to which 2 p.ct. additions had been made of oxide of iron, sodium carbonate, and calcium carbonate.

In the first place there are interesting results in gas yield, &c., with which Dr. Parker will deal. As far as the appearance of the coke went, this was not very different in the special case from what it was with ordinary coke. The difference had apparently been wiped out by the more protracted period of carbonization. When the reactivities were tested, however, it was obvious that this enhanced reactivity of the coke was retained—that it was just as much a feature of large-scale carbonization as it was of laboratory carbonization.

I would just like to refer to one other interesting point, because I think some of you may possibly have had experience which it would be useful to us to know of in this connection. If you take the results that were obtained by the addition of lime, as have been claimed since the time of Cooper, a very enhanced evolution of ammonia and recovery of ammonia were made possible. About one-third more ammonia was obtained with the lime, and also a much lower sulphur content. The same thing was noticed with oxide of iron. A much lower sulphur content was obtained in the gas, and necessarily a much higher sulphur content was found in the coke. When one comes to consider whether this can be of practical service or not, one has to face the question whether the advantage of a high sulphur coal giving a gas which is low in sulphur is more than counter-balanced by the high sulphur content of the coke. This brings me to the particular question I wish to raise. When experiments were made in the laboratory on this high sulphur coke containing lime, on gasification in steam we found that very little of that sulphur was liberated. Thus in the laboratory manufacture of water gas a low sulphur water gas was obtained, though it was a high-sulphur lime coke. I do not know whether in the past—because this liming process has been tried at various times in many quarters—information has been obtained on this point; whether it is practicable by the addition of lime, dealing with a high sulphur coal, to get a low sulphur gas and also send the coke on to the water gas plant to obtain a low sulphur water gas at the same time.

Dr. A. PARKER then gave an abstract of the report.

Discussion.

The PRESIDENT: I am particularly anxious to keep to the authorized time of the meeting; but it is now 5.30, and I feel I cannot accept the responsibility of the discussion on such an important subject as this being curtailed in consequence of the reduced attendance. I should therefore like your views as to whether you would prefer that the discussion should take place now or should be adjourned till to-morrow morning.

Mr. THOMAS GLOVER (Norwich): I think in the interest of those who have remained, the discussion should take place, because apparently these are the people who are most interested.

Another speaker suggested that the discussion should be adjourned until the following morning.

The PRESIDENT: I think there is a general desire that we shall proceed with the discussion. I will not detain you long, but I cannot help saying that the reading of the report recalls to me—and I daresay it recalls to others present—the case of the old village blacksmith and his mysterious box of some fine powder which he carried in his waistcoat pocket when he was called upon to carry out what he called a special weld. I have seen it done on many occasions; and the little résumé by Dr. Parker brought that back to me. Of course, on those occasions wild horses would never drag from the village blacksmith what that powder was; but if you were patient, and just hung on until you caught him "market merry," you would gradually get it from him that it was nothing but powdered limestone, or powdered common washing soda, or some similar material. In those days I used to think the man had gone mad; but when all is said and done there was some form of method in his madness, and it only showed in how humble a manner research work really commenced. These old blacksmiths must have done something to have found out the virtue, small though it be, of applying a foreign substance, such as sodium carbonate, in order to enable them to get a higher and a quicker heat. At any rate it does show that even in those days research was taking place.

Mr. C. F. BOTLEY (Hastings): The question was asked a little while ago whether the old liming process was still in use. It would be interesting to hear anybody give Prof. Cobb an answer. So far as I have ever heard anything of it, it was practised last on any scale at Tunbridge Wells, but I believe it was given up; and I am not sure that it is practised anywhere deliberately now. Of course, the whole object was to reduce the sulphur compounds; but since we have had freedom from exacting legislation with regard to these, the necessity has not arisen for its use. There is, of course, a most interesting point arising from this. If we can use the old liming process with certainly some attendant advantages—and remembering that we may be using silica retorts, we have to be very careful what we do with such things—and if we can utilize the coke which contains, due to the admixture of lime, a rather larger proportion of sulphur, and the latter is not liberated again as gaseous sulphur compounds in a carburetted water gas plant, it does, of course, open out another avenue of considerable utility.

I cannot help thinking that it would have been most valuable had we been able to have this report before Mr. Carmichael's paper, because, by a curious coincidence, these experiments and their theory underlie most of the cases which cropped up in a practical form in Mr. Carmichael's paper and the discussion upon it. Had we been able to arrange this discussion first, and then to have had the practical discussion on Mr. Carmichael's paper, it seems to me that it would have had a very great moral value.

There is a point I want to ask Dr. Parker about. If you look at the results per ton of coal carbonized given in the report, you will see that the tests are given for the mixtures.

It will be sufficient for my purpose if I refer to the gas made per ton, because the figures follow very much all the way down. You get certain figures for sized coals dealt with separately; and if you mix the two together, which is what happens in practice, it appears to me that you get a rather better result. I have just been hearing, as the result of practical experience, that with vertical retorts, for reasons into which we need not go, if there is a separation of the large coal and the fines, and the large coal is used in the vertical retorts, we get a better result; but Dr. Parker, in the remarks he made, rather gave me to understand that this report supported the separation and the carbonization in sizes, whereas the tests in the report, as I read them, give a different impression.

I find this admixture of foreign matter with cokes a most fascinating subject, and I cannot help again emphasizing the extraordinary results we seem to get from the admixture of sodium carbonate. If we are going to get the increased thermal values which have been suggested, without detrimental factors coming in, without trouble in the carbonizing plant or difficulties as regards coke, it does seem to be a great help in carbonizing practice. I would remind you that last year, in the discussion on a similar matter, some speakers referred to accidental admixtures of coke, such as watering it accidentally with ammoniacal liquor. One gentleman said he had found that people who had bought this coke which had been treated with liquor came back, not as was thought at first to complain, but because they wanted more like it. Another feature is that those of us who are near to the sea often get the sea when we do not want it; but when we get it on the coke, it has been found to be a remarkable help in burning in grates. Coke which has sea water upon it burns with great ease.

Mr. BERNARD KELHAM (late of Perth, Australia): This matter of liming was fully dealt with by Mr. Stephenson, of Long Eaton, during the war; the principal object then being to reduce the sulphur compounds, oxide being rather difficult to obtain. Some remarkable results were obtained in curing stopped pipes at Long Eaton. In connection with Dr. Parker's remarks about sulphur being retained in the coke, I presume the sulphur remains in the ash after the water gas process. What would be the result of mixing lime with the coal in vertical retorts, and then steaming at the bottom? Where would the sulphur go to? I presume it would remain in the coke; but it is a point I would like Dr. Parker to explain.

Mr. THOMAS GLOVER (Norwich): I have to apologise that I was not able to attend the meetings of the Committee last year; but I have followed the work closely, and have read this report with great interest. I find that the experiments have been confined to the same Nottinghamshire coal as last year; and it appears to me a pity that the investigators have confined themselves entirely to that coal when they were in the midst of the Yorkshire coals, which are used so generally throughout the country. Concurrently with these tests, tests on other coals might have been carried out. The question of heat transmission has come before our notice largely to-day, and I remember it as one of the points we discussed in setting out the programme for last year's work—the question of the size of coal, the temperature applied to the coal, the thickness of the charge, &c. It is all a question of heat transmission; and I take it that the reason why the gas is given off more liberally with coal of the nut size rather than the small coal is that the radiant heat penetrates, and is transmitted much more quickly to the coal giving off the gas.

The report states that "the thermal value of the total gas may increase from 72·3 therms per ton with the grade of coal 1¼ in., to ¼ in. to 75·8 therms with the grade 10 to 30 mesh, but this increase in the thermal value of the gas with the smaller size of coal was obtained by a decrease in the yield of tar." I take exception to the word "but." I should have said "and as was to be expected, this increase . . ." There was a decreased yield of tar; and where would you expect to get the gas from if you did not get it from the tar? I take it that it follows there would be a decreased production of tar in an experiment of this kind with the increased yield in volume of gas or thermal value. Then there is the statement that "the structure of the cokes produced from the different sizes of coal was also examined. The coke from the 10 to 30 mesh coal was more uniform in structure than that obtained from the larger sizes." This also is what one would expect. One would expect that from very small coal the coke would be more uniform; and this remark in the report sounds a little commonplace to me.

I should like to have seen in the report a summary showing the significance of the result of the year's work to the gas maker. What are we to learn from this investigation? That is really what we are after. It is no use our having these investigations unless we have something practical as a result of them. For instance, there is this question of the additions of oxide of iron, calcium carbonate, and carbonate of soda. I do not think it is sufficient to give us the results which follow these additions. I think we might be favoured with some conjecture or some reasoned explanation why these results follow the additions of these chemical substances. It is not enough to tell me that, if I add some sodium carbonate to a charge of coal, it is going to give an additional thermal yield. It is natural for a technical man or a scientific man to inquire what is the reason; and this is where we would expect our research chemists to help us.

With regard to the ignition points, I can understand these substances affecting the ignition points of the coke, and I can also understand their effect on the reactivity in the presence of steam. I am not, however, disposed to believe that the sodium carbonate raised the ignition point of coke. I have observed coke with certain amounts of sodium, and have found that the reactivity is considerably increased when the sodium is present. Whether the ignition point has been raised or not, I am not certain; but what I do know is that the reactivity is greatly increased in the presence of oxygen when you have attained a certain temperature. This is one of the matters of real interest, I think, in this report. Whether these points affect our practice or not, however, is a great question. I cannot imagine discharging coal into our hoppers, and a man emptying a barrowful of carbonate of soda into the hopper at the same time, or sprinkling it with a shovelful of carbonate of soda, or oxide of iron, or calcium carbonate. I have heard of coal being lime-washed in order to get a good distribution of lime for the extraction of sulphur; and I believe it is a good way of doing it. Another point which has not been discussed is the effect of the use of alkalis on the refractory material. If anyone has attempted to follow the suggestions that are given in this report in order to try to get a higher thermal value in the gas from the use of sodium carbonate, I would ask him to look after his silica retorts.

Mr. F. G. SHAW (Buxton): As you know, the coal liming process was for the purpose of reducing the sulphur compounds, and no doubt figures concerning it are available. It would be useful if they could be given in the report, as it would be very interesting to know if, by the addition of some material to the coal before carbonization, we can reduce the amount of sulphur compounds other than sulphuretted hydrogen. I believe a very great deal of the trouble we have had in keeping lighting fittings in good order is due, to a large extent, to the fact that purification from sulphur compounds was in the past so much neglected. I believe the vertical retort does give a gas containing, perhaps, only about 60 p.ct. of the sulphur compounds which you would get by carbonizing the same coal in horizontal retorts; and I believe this is one of the unsuspected reasons why vertical retorts have proved to be so satisfactory. I have been taking a great deal of interest in the question of oil washing to remove sulphur compounds; and I believe it is generally known that if you use rather more than the usual quantity of oil with naphthalene washing, you remove a certain quantity of sulphur compounds. If figures as to the sulphur compounds present as the result of adding these various substances to the coal prior to carbonization were given, they would be of extreme value.

Dr. PARKER, replying to the discussion, said: Mr. Botley mentioned the liming process, but we ourselves are really asking for information in connection with the liming process, because if one looks up the ordinary chemistry literature one comes to the conclusion that sulphur retained in the ash of coke as the result of adding calcium carbonate should fairly easily be liberated. Steaming apparently does not do so; and that is why we are asking for information. We cannot give the reason. Mr. Botley also raised the point of the gas made per ton of coal. In this connection I think I must mention that when we carry out experiments on carbonization, we carry carbonization practically to completion as far as the particular temperature is concerned. We do not suppose that in large-scale work carbonization would be continued to the same extent. If you leave the coal at 900° C. for too long a time, you have driven off all the gas that is available at that temperature; and this is the reason the gas makes to which Mr. Botley referred are all approximately the same. In carbonization on the large scale, however, one has the outside of the fireclay retort at perhaps 1300° or 1400° C. supplying the coal inside probably at not more than 1000° or 1050° C. You are using a big temperature drop for rapid carbonization; and that is why the rate of gas production comes into play. It is with the larger sizes of coal that we get higher rates of gas production. One can, therefore, carry carbonization to a definite stage more rapidly with larger sizes of coal than with small coal, or more rapidly with either size than with the mixtures. Mr. Botley also referred to watering coke with sea water or ammoniacal liquor as improving the reactivity; and I take it that the action is somewhat similar to that of impregnating coke with a sodium carbonate solution. Mr. Kelham mentioned the retention of the sulphur in the coke, and the effect of steam in continuous vertical retorts. This problem is really similar to the one I have referred to, and on which we have no information. As to the addition of lime, as far as the experiments at Long Eaton were concerned, it was claimed that, by adding lime to the the coal, larger yields of toluene and benzene were obtained.

Mr. Glover regrets that we have so far only carried out experiments on Nottinghamshire coal. The fact is simply this. We have got a very big programme on the effect of sizes of coal, admixture of sizes, and temperature, and different types of coal. So far we have covered two temperatures. We have still to go on to lower temperatures; and we shall continue

the work with other coals. We do not propose to stop simply with this coal; but Nottinghamshire coal was chosen in the first instance merely because we had obtained reliable results on a test plant—full-scale retorts—with this coal. The difference in rate of gas evolution with different sizes is due, we think, as Mr. Glover mentioned, to the method of heat transmission—that the larger pieces of coal retain heat, and this heat is carried by convection into the space between the different pieces of coal. When one takes small coal, then the transference of heat by flow of gas within the retort is more restricted, and a lower heat transmission occurs. On mixing the two sizes, one has the restricting influence of the small coal between the larger pieces preventing heat transmission by flow of gas. The larger pieces themselves really reduce the fine coal to molecular division, and it is all forced together. The result is that you get a lower rate of gas evolution from a mixture of sizes of coal. Mr. Glover has stated that we ought to be able to give an explanation for the greater gas makes resulting from the addition of sodium carbonate. An attempted explanation is given in the report itself, where it is pointed out that a lower yield of liquor is obtained on carbonizing with sodium carbonate; and the suggestion is put forward that the liquor evolved from the centre of the charge passes over the more highly reactive coke on the outside of the charge, and is decomposed.

Mr. GLOVER: I am much obliged to you for that information.

Dr. PARKER: We cannot give the reason for the greater reactivity of sodium carbonate towards steam. We do not know exactly what it is. The matter is to be discussed further in the Gas Fellowship Report which is to be presented to-morrow morning. As to the reactivity of gases towards steam, and the ignition temperatures, perhaps Mr. Glover has misunderstood me in regard to the ignition temperature of sodium carbonate coke. If one carbonizes coal with sodium carbonate, and cools the coke rapidly in air, and then tests it for ignition temperature, one obtains a high ignition temperature—higher than from coke prepared from the coal alone. If, however, one allows the coke to weather for a few days, one obtains a lower ignition temperature than if one cooled the coke in the first place by quenching it with water. We do not know the chemical explanation of this, but we hope to find it later.

In reply to Mr. Shaw as to whether sodium carbonate should be mixed with the coal before carbonization, this is not suggested in the report, because we know full well that it would cause deterioration of the retort. Mr. Shaw also asked about sulphur compounds in the gas other than the sulphuretted hydrogen. We have no information on this subject. In an experimental plant of this type, in order to obtain accurate results we remove the ammonia with a solution of dilute sulphuric acid, and the sulphuretted hydrogen with caustic soda. Therefore the results for sulphur compounds other than sulphuretted hydrogen in the gas would be different from what one would obtain in large-scale practice using iron oxide purifiers. Furthermore, it introduces complications, and would have caused delay in the work, which we thought was not warranted by the information which would be obtained.

On the motion of the PRESIDENT, the report was then adopted.

GAS AND ELECTRIC WASH BOILERS.

A Practical Test.

From Mr. George W. Anderson, of Messrs. Anderson Bros., 5, Victoria Street, S.W., we have received particulars of a test made at Ludlow between a gas wash copper and an electric one. The test—simple and practical—was made by the Borough Surveyor of Ludlow in the presence of the Gas Manager and the Electrical Engineer. As the result, the Gas Company obtained the order for 32 wash-boilers. The report on the test is as follows:

Test between Richmond's "Greyfriars" gasheated wash-copper and the Shropshire, Worcestershire, and Staffordshire Electricity Company's "Creda" electric wash-copper.

Price of gas . . . . . 15d. per therm.
Price of electricity . . . . . 1½d. per unit.

Before the Mayor of Ludlow and Members of the Corporation Housing Committee.

	Gas Wash-Copper.	Electric Wash-Copper.
Initial temp. of water . . .	65° Fahr.	65° Fahr.
Final " " . . .	210° Fahr.	210° Fahr.
Quantity of water boiled. . .	6 galls.	6 galls.
Time taken	46 mins.	58 mins.
Fuel used	30 c.ft. of 500 B.Th.U. gas	3·1 units of electricity.
Cost	2·2d.	4·65d.

Gas, 111 p.c. more efficient in cost.
" 26 p.c. " " time.

Gas copper, £2 12s. 6d., fixed free, and guaranteed for two years.
Electric copper, £5 2s. 0d., fixed free.

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BECTON, BOXHILL, N.S.W., BRECON, BRIGHTON & HOVE, BROMLEY (repeat), CROYDON, KNOWLE, OMORI (Japan), PORTSMOUTH, RETFORD, STRATFORD, E., STRETFORD, TOTTENHAM (two repeats), WELLINGBORO'.

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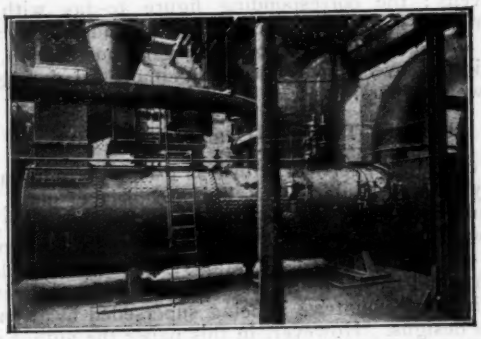

Up to 5¾ lbs. of Steam per lb. of Coke put into the Producers have been obtained from Non-Regenerative Horizontal Retorts by means of these Boilers.

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OVENS AS A GAS-WORKS CARBONIZING PLANT.

By G. M. GILL, M.I.Mech.E.

It is thirteen years since a paper on ovens was read before this Institution. In 1914 Mr. W. Chaney read a paper on "Coke Oven Carbonization," which embraced a description of the ovens installed at the Saltley Works of the Birmingham Gas Department. At the 1907 meeting there were no less than three papers on ovens. One on "The Carbonization of Coal, with special reference to the Bye-Product Coking Process," was read by Mr. Ernest Bury, of Little Hulton; one on "The Financial Significance to the Gas Industry of the Modern Bye-Product Oven," by Mr. Paul Schlicht, of New York; and one on "Notes on the use of Excess Gas from Bye-Product Coke Ovens for Lighting and Power Purposes," by Mr. C. E. Rhodes, of Rotherham.

It would appear from Mr. Bury's paper that coke ovens were then carbonizing about 5 tons of coal per oven per 24 hours, and that 8 to 10 tons was a high figure. The modern full-size oven to-day, with an internal cubic capacity 30 to 50 p.ct. greater, carbonizes about 24 tons a day. In Mr. Bury's paper it was stated that 3000 c.ft. per ton was a good figure for surplus gas—*i.e.*, after heating the ovens; the corresponding figure to-day with the modern oven is over 7000 c.ft. It can, indeed, be confidently stated that the science of design, construction, and operation of ovens has enormously improved during the past twenty years.

Present Types of Carbonizing Plant.

The continuous vertical retort, as used so largely in this country, is a particularly well-designed piece of plant, and very suitable for the purpose for which it is intended. It has few disadvantages, and fully meets the requirements of gas engineers for most situations; but so favourable an opinion could hardly be extended to the horizontal retort, which in other countries is being superseded by ovens of various designs. However, in this paper the author does not propose to compare the oven with alternative types of carbonizing plant, but rather to put a few facts about ovens before the members, who probably for the most part have not had the opportunity of seeing the various types of ovens in operation, as has been the author's privilege on many occasions during the past few years.

Is Oven Coke Suitable for Ordinary Use?

The author first seriously investigated the suitability of ovens for gas-works in 1920; and then his only real doubts in regard to their advantages under English conditions lay in the question of the coke. Would it be as saleable as vertical or horizontal retort coke? His general conclusion then was that, where there was a good sale for metallurgical coke, ovens were very suitable for large gas-works as part of their carbonizing equipment; but where little or no sale existed for such coke within a reasonable distance, then they could still be considered as suitable for part of the carbonizing plant, as a substantial proportion of coke users would prefer that grade of coke, and would be prepared to pay a good price for it.

The question to consider now is whether oven coke generally is suitable for the purposes for which gas coke is sold. The author's view is that it is quite suitable for all purposes except for use in open grates, provided, of course—and this is equally important with gas coke—that it is supplied of the correct size for the particular appliance in which it is to be used.

The whole position in regard to coke sales has undoubtedly altered very considerably in the past few years. The rapid development of the coke boiler, and its general adoption in most new housing schemes, and in numerous instances where house property is being modernized, has led to its use in tens of thousands, and has created a large demand for this class of coke stove. Consequently there seem to be good reasons to anticipate that a gas undertaking in the future will only have to keep the moisture low, the ash reasonably low, and, what is essentially of the greatest importance, to supply the coke in three properly graded sizes at least, other than breeze, to sell its whole production in its own district; whether it be coke from horizontal or vertical retorts or from ovens, is immaterial. Ordinary selling ability is, of course, assumed.

That oven coke of the right size will burn very satisfactorily in these coke boilers, the author can say from personal experience in his own house; and in that instance the draught would be described as poor—the chimney to the boiler being but 18 ft. in height.

The Small Horizontal Oven.

The author has seen many small oven installations; but he would not suggest that these should be considered for any works which is not large enough to put in a carbonizing plant to make 300,000 c.ft. a day, or, alternatively, which is not large enough to justify through horizontal retorts with a combined charger and discharger. In adapting the ovens to the smaller gas undertakings, these are made of various sizes ranging from a coal capacity of 2500 lbs. to one of 4000 lbs. for a carbonizing period of 12 hours.

The small ovens have until recently been built in a setting of three ovens with one producer; and consequently the unit consisted of three ovens, equivalent in carbonizing capacity to a horizontal setting of eight through retorts. A typical installation with this arrangement is seen in figs. 1 and 2 appended, in which there are four settings, or four units, each with one producer and three ovens; the whole being an adaptation from the settings of nine horizontals, one oven with charging opening at the top taking the place of three retorts. In this case the gas company has a total annual make of under 200 million c.ft. of coal gas; and for such a size of works, the small oven settings have been very successful.

While the illustrations are largely self-explanatory, particulars are given below of the design and arrangement as shown:

1.—The heating of the ovens is exactly similar to a setting of nine horizontal retorts.

2.—The charging is through two openings in the top from a power-operated wagon; each charge being weighed, and the coal being stored in an overhead hopper (not shown) at the end of the bench.

3.—The size of ovens in this case is 12 in. wide by 8 ft. high by 13 ft. 6 in. over-all; the charge being 4000 lbs., which can be carbonized in 10 to 12 hours.

4.—The coke is discharged by a pushing machine, which is also fitted with a ram for levelling the charge of coal through doors in the top of the ovens; the machine is further provided with apparatus for removing and replacing the oven doors.

5.—The coke is generally pushed-out into a travelling coke wagon in which it is quenched by a spray, and a fixed quantity of water turned on automatically by the wagon at the end of the bench. The coke is then emptied out upon the sloping coke wharf for cooling and preliminary storage, prior to being discharged to a rubber belt conveyor, which delivers it through a breaker, if desired, to the same elevator as handles the coal; the coke being diverted at the top into screens, after which it is stored in its various sizes in an overhead hopper.

6.—The gas passes out through one ascension pipe, and is dealt with as in a retort setting.

7.—The producers in this case are adapted for burning coal or coke. So far the author has not seen an oven installation in which hot coke is fired into the producers.

Labour Required.

12 ovens, each carbonizing 2 tons, or 48 tons in all per 24 hours.

1 pusher driver and fireman per 8 hour shift, or 2 men in all.			
1 coal wagon operator and top man	do.,	2	do.
1 coke do. and quencher	do.,	2	do.
1 fireman on one 8-hour shift		1	do.
Total		7	men in all.

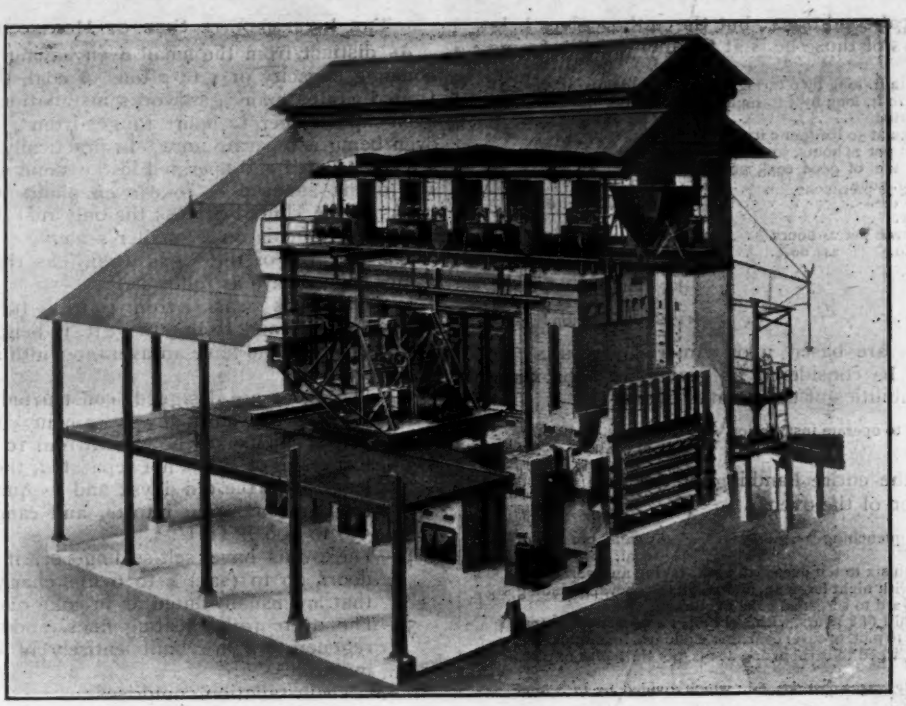

Fig. 1.—General Arrangement of Small Horizontal Ovens. (Improved Equipment Co.).

In actual practice over a year's working, this amounts to 1·25 man-hours per ton of coal carbonized. It is stated that this number of men is sufficient for a plant of 50 p.ct. larger capacity.

Results.

A plant of this description shows the following results for a complete year's working:

Gas made per ton	13,700 c.ft.
B.Th.U. per c.ft.	530*, or 72·5 therms per ton.
Tar made per ton	11 galls.
Fuel used	15 lbs. per 100 lbs. of coal.
Coke made per ton of coal	14·76 cwts.
Coke *ex* retort house per ton of coal	11·76 cwts.
Coal charged per oven	34·4 cwts. per 24 hours.
Gas made per oven	47,100 c.ft. per 24 hours.
Do.	249 therms do.

*Estimated.

At Pontiac (Mich.) there is an installation of 60 small horizontal ovens of this type and size, these having proved successful, and been extended from time to time. There are also similar installations of the same size and type of oven at several other gas-works, most of which the author has visited.

THE SMALL HORIZONTAL OVEN IN SINGLE UNITS.

For smaller works, the ovens are now being built as separate units, each of which will carbonize 22·3 cwt. of coal per 12 hours. By this means, the size of unit has become equivalent to one horizontal retort setting of five single-ended horizontal retorts, and with equal facilities, as each has its own recuperator, and all the ovens are heated by producers—one or two—common to all the ovens.

Ovens, however small, require the use of a coke pusher, a coal truck, and a coke wagon, all mechanically operated, and for this reason there is a distinct limit to the size of undertaking which is justified in laying out the necessary capital for such an installation. For a works of the smallest size indicated above, ten small ovens would make 300,000 c.ft. per diem; and these could be extended one by one as required—the two producers at the end of the bench being enlarged or increased in number at the appropriate time.

The small ovens in question can be varied in dimen-

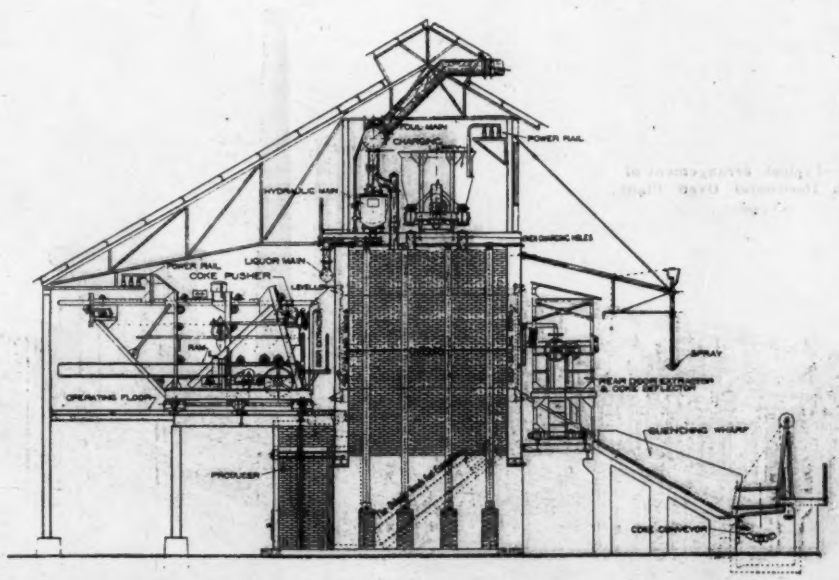

Fig. 2.—General Arrangement of Small Horizontal Ovens. (Improved Equipment Co.).

sions to suit local conditions; but the author gives below a few particulars of those he is at the moment discussing:

Size (internal) 12 ft. long by 6 ft. high by 12 in. wide (parallel).	
Coke space . 10 ft. long by 5 ft. high by 12 in. wide.	
Carbonizing period	12 hours.
Weight of charge at 50 lbs. per c.ft. . .	2,500 lbs.
Coal carbonized per 24 hours, 5000 lbs. =	2·23 tons.
Gas made per ton of good coal, producing 70 p.ct. coke.	13,440 c.ft.
Calorific value	530 B.Th.U. per c.ft.
Therms per ton.	71·25
Gas made per oven per 24 hours . .	30,000 c.ft.
Therms do. 24 do. . . .	159
Fuel used	333 lbs. of coke per ton of coal, or equal to 15 p.ct.
Tar produced	11·2 galls. per ton.

These figures are based upon American results; and they must only be considered as giving an approximate idea of the capabilities of these small ovens.

Power required to operate installation . .	8·62 KW.-H. per ton of coal.

This covers the entire handling of the coal and coke, and the operation of the ovens.

Water used for quenching.	465 galls. per ton of coal.

Labour cost with six to ten ovens at work, taking an average of eight ovens, with night foreman, and results as above, including from coal in yard to screened coke in storage.
Two men per shift of 8 hours, with 2 shifts, or 4 men in all at 10s. per shift, *plus* 10 p.ct. to cover overtime, holidays, insurance, &c.
One foreman charged to carbonizing at 15s. per shift, *plus* 10 p.ct. for extras.
Then, total daily wages cost 60s. 6d., which divided by 17·8 tons coal carbonized,

= 40·8 pence per ton of coal.
= 3·04 ,, ,, 1000 c.ft.
= 0·57 ,, ,, therm.

Such an installation would embrace the same type of plant as described above, except that each oven has its own heating flues and recuperators, and there are common producers to all the ovens. Further, this type is being provided with facilities for heating the ovens by coal gas. A plant of this description, to make 300,000 c.ft. a day, will shortly be put to work in the United States.

With small horizontal ovens, the coke, with 12 hours' carbonizing, as is usual in the United States, is not unlike horizontal retort coke, though it has the appearance of being rather harder, but no larger, with a smaller percentage of breeze. The ovens seem to the author to be specially advantageous when using coals which do not coke very well, or which make too much breeze in verticals or horizontals.

The method of handling the coke, first in slowly discharging the oven, secondly in receiving the coke in a large wagon for quenching, thirdly in discharging from the wagon to an inclined floor, and fourthly in sliding from this floor on to a rubber belt conveyor or into bogies or telpher skips, certainly deals gently with the coke; and this undoubtedly accounts in some measure for the small amount of breeze produced.

The Intermediate Size of Horizontal Oven.

As distinct from the small oven having a 12-hour carbonizing capacity of 1 to 2 tons of coal, there are in the United States many gas-works installations in which the oven capacity per 12 hours ranges from 4 to 6 tons, each oven being a separate unit. In practically all cases these are constructed and operated in the same way as the full-size ovens as used in coke oven plants and large gas-works in the United States; the only real difference being that everything is on a smaller scale.

The features of the "gas oven," as this size is commonly termed, are as follows:

1.—The ovens measure from 19 to 24 ft. in length from door to door, from 9 to 13 ft. in height, are slightly tapered, and have an average width inside of about 13½ in.

2.—The ovens are designed, constructed, and operated to carbonize normally a 12-hour charge; but the period can usually be varied from 10 to 24 hours.

3.—The make of gas is not separated, the rich from the lean, as in the old days; and its quality is entirely the same as from retorts, and ranges from (say) 530 to 600 B.Th.U.

4.—The ovens have self-sealing, or, if desired, luted doors up to (say) 4 to 6 ton charges, and above that are usually luted as in coke oven practice.

5.—The oven walls, heating flues, and top portion of regenerators are built entirely of 95 p.ct. silica material.

6.—Each installation comprises:

(*a*) An overhead coal storage hopper.
(*b*) A travelling coal wagon to charge the ovens through the top.
(*c*) A pushing machine, with door handling gear either fitted to the machine, or separate in large installations.
(*d*) A coke wagon, with door handling gear fitted to the machine, or separate in large installations.
(*e*) A quenching tank at the end of the bench.
(*f*) A coke wharf to receive the coke after quenching.
(*g*) A rubber belt conveyor to take the coke from the coke wharf to the screening plant.
(*h*) Regenerators on the Siemens system of reversal usually every 20 to 30 minutes.
(*i*) Automatic reversing machine.
(*j*) Mechanical producer plant to use small coke, and breeze up to 40 p.ct. of the total fuel; the producer being fitted:

1.—With boiler in the shell of the producer to generate steam for its use; and
2.—With waste-heat boiler to extract the sensible heat of the producer gas, and to provide all the steam required for working the entire producer plant, consisting of mechanical clinkering apparatus, elevator, scrubber with pump to wash the gas thoroughly, and fans to supply the ovens with producer gas and air.

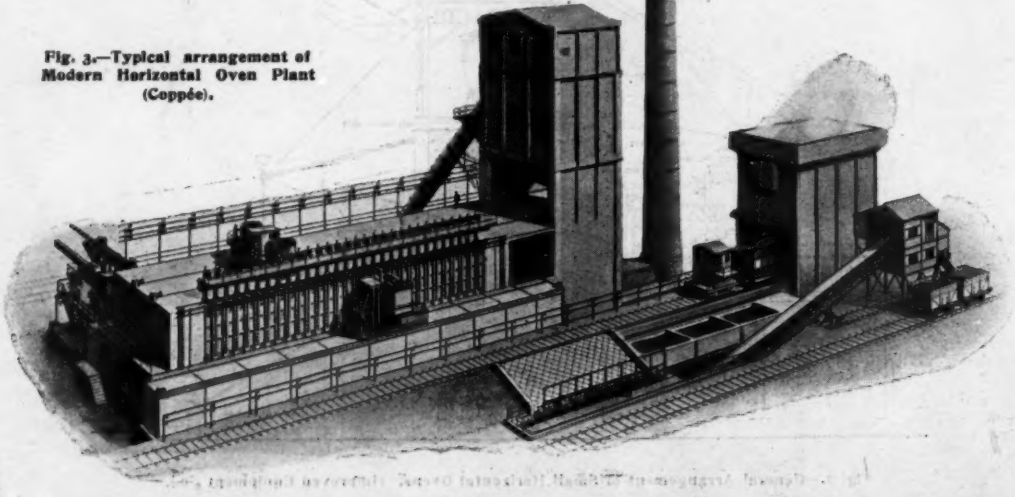

Fig. 3.—Typical arrangement of Modern Horizontal Oven Plant (Coppée).

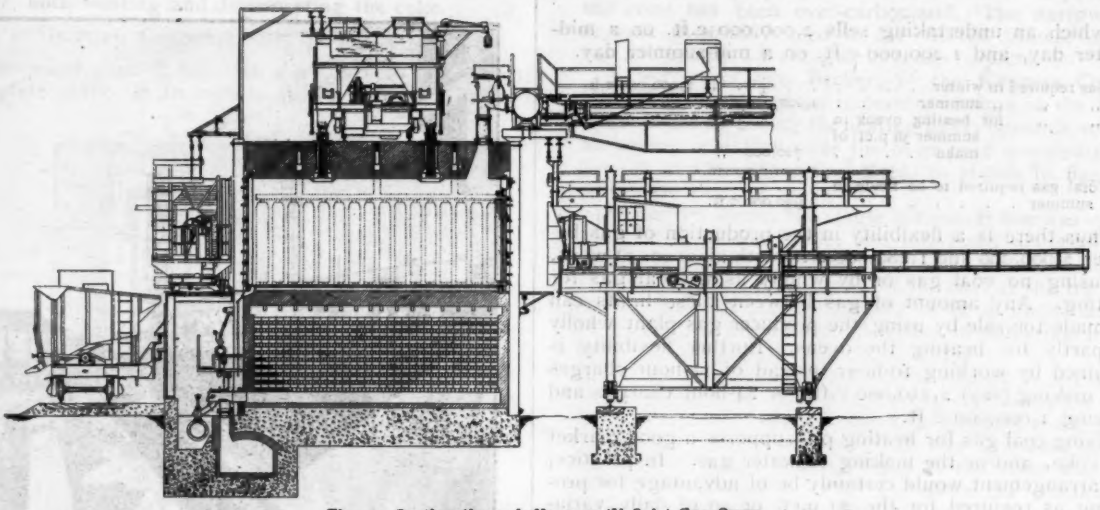

Fig. 4.—Section through Koppers (U.S.A.) Gas-Oven.

(*k*) The necessary pipes, cocks, and equipment to supply coal gas or producer gas, as desired, to any or all of the ovens.

(*l*) One ascension pipe, valve, and hydraulic main to each oven.

(*m*) A mechanically operated governor to regulate the exact vacuum required on the ovens.

Fig. 3 shows a typical lay-out for the modern gas oven plant; while fig. 4 gives a view of the machinery and the general arrangement of the ovens. It will be observed that the small ovens first described are in many respects large ovens in miniature.

Table I. gives dimensions and capacities of a number of oven plants of intermediate size installed recently in gas-works in the United States.

The intermediate size of oven, as used by American gas-works, will frequently be fitted with coal pulverizing and blending plant, as are a number of those included in Table I., to enable two coals to be properly mixed and prepared for making metallurgical or foundry coke. Whether this is or is not done, merely depends upon the coal in use and the local demand for such coke, as these ovens are quite suitable for making this type of coke.

These modern oven plants work at very low labour cost. At the Fort Wayne Gas-Works, which the author visited, there is a total gas-making capacity of 5,000,000 c.ft. a day, of which 2 million c.ft. is water gas. Their normal daily output varies from 3,350,000 to 4,750,000 c.ft.; and the entire gas-works plant was run by 73 men —and that was under winter conditions.

Flexibility in Gas Production.

In order to make ovens more adaptable to gas-works operations the Koppers Company of America introduced the flexibility in gas production which has been rendered possible by the provision of mechanical producers and divided regenerators for pre-heating both producer gas and air, to enable producer gas to be used as an alternative to coal gas. It is necessary in gas-works to vary the make from 100 p.ct. on the heaviest day down to 50 p.ct. on the lightest day; and if this has to be done solely with coal gas plant, and that plant consists of ovens, then one or a combination of the following means is adopted:

1.—The ovens are dropped or picked-up in the same way as retorts.

2.—The ovens are put on longer carbonizing periods, with lower heats, up to double their normal duration.

3.—One or more, or the whole, of the ovens are heated by coal gas, and the producer plant is partly or wholly shut-down.

Various means are adopted in the United States; while the last-named arrangement is adopted also for the purpose of making more coke for the market. Under certain conditions in England, and frequently in the United States, it pays to use coal gas for heating the ovens, and to sell the coke thus released—especially if there is also a good tar market. The author would refer to the opinions expressed by Mr. W. M. Carr in his paper to the Institution in 1925, in which he showed that under certain conditions it would pay to use coal gas for heating the retorts at Stretford. In the United States, where central heating is in general use, coke has become a satisfactory substitute for anthracite, which is expensive and scarce; and consequently it is frequently the case that coke will fetch a price 50 p.ct., and sometimes nearly 100 p.ct., higher per ton than the coal costs delivered at the gas-works.

With the possible general adoption in the future of the coke boiler in the house, it is by no means unlikely that coke, if of good quality and properly graded, will sell for high prices in many districts in England, and make it economical to keep the carbonizing plant at work throughout the year, and periodically to use coal gas for its heating. In this connection, it will not be overlooked that hot water other than for central heating is required in fairly equal quantities in both summer and winter

With this possibility in mind, let us take a concrete case

Table I.

—	No of Ovens.	Length Face to Face of Doors.	Height Inside.	Average Width Inside.	Taper.	Weight of Charge. Tons.	Daily Gas Output in Thousands. C.Ft.	Quality B.Th.U. per C.Ft.	Type.
		Ft. In.	Ft. In.	In.	In.				
Saginaw	19	20 7½	9 11	13½	¾	4·82	2500	..	Koppers Becker Oven
Zilwaukee	19	20 7½	9 11	13½	¾	4·82	2500	550	,,
Battle Creek	11	23 8½	10 0	13½	¾	6·07	1900	550	,,
Winnipeg (Canada)	17	23 8	10 10	13½	¾	6·07	3000	550	,,
Utica	21	Approximately as Winnipeg above					3500	550	,,
Fort Wayne	19	,,	,,	,,	,,	,,	3000	,,	,,
Lynn	11	,,	,,	,,	,,	,,	2000	,,	,,
Jackson (Mich.)	15	17 6½	9 5½	13½	¾	3·88	1560	,,	,,
Rochester (N.Y.)	37	19 1	13 0	13½	¾	5·88	5000	,,	,,
Kalamazoo (Mich.)	15	21 3	8 8	12⅜	2½	3·57	1440	..	Parker-Russell

All the above plants are supplied with one or more mechanical producers; and the ovens can be heated, as desired, by coal gas or producer gas. The producers are fed with small coke and breeze; the latter amounting to 35 to 40 p.ct. of the mixture. The make of gas on coal gas firing is about 65 p.ct. of the make on producer gas firing; any make between these two limits being obtainable by using coal gas firing partially only. The above ovens are mostly built at 3 ft. 6½ in. centre to centre. The carbonizing periods are normally 12 hours; but these can generally be varied from 10 to 24 hours.

in which an undertaking sells 2,000,000 c.ft. on a mid-winter day, and 1,200,000 c.ft. on a mid-summer day.

Gas required in winter	2,000,000 c.ft.
" " " summer	1,200,000 c.ft.
" " for heating ovens in summer 36 p.ct. of make	720,000 "
Total gas required to be made in summer	1,920,000 c.ft.

Thus there is a flexibility in the production of gas between 2,000,000 and 1,280,000 c.ft. with all ovens at work, by using no coal gas or by wholly using coal gas for heating. Any amount of gas between these limits can be made for sale by using the producer gas plant wholly or partly for heating the ovens. Further flexibility is obtained by working 10-hour instead of 12-hour charges and making (say) 2,250,000 c.ft.; or 24-hour charges and making 1,000,000 c.ft.

Using coal gas for heating pre-supposes a good market for coke, and/or the making of water gas. In practice, the arrangement would certainly be of advantage for providing as required for the 20 p.ct. or so of daily variations in the demand for gas without recourse to a water gas plant.

Time will not permit of any discussion on the economics of the relative cost of using coke or coal gas for the heating of carbonizing plant; but this question is closely connected with the careful preparation and marketing of coke. The fact that most coke oven concerns use coal gas for this purpose, while using inefficiently or wasting the remainder, and are presumably able to make a profit from coke and bye-products alone, indicates that the possibilities outlined above are by no means fantastic.

THE LARGE HORIZONTAL GAS OVEN.

Prior to 1919 there were only some six gas-works in the United States using full-scale ovens as carbonizing plant, but there have been for a long time many gas undertakings, notably in Chicago, Detroit, Boston, Baltimore, and Cleveland, taking large quantities of gas in bulk from coke oven plants.

Of gas supplied to towns, considerably more coal gas is made in ovens than in retorts; and the difference is steadily increasing, especially now that many gas-works are adopting ovens instead of retorts. In a country where carburetted water gas is used so largely, and frequently exclusively, for the supply of towns, it is easier than in England to take bulk supplies of coke oven gas, which might fail at short notice, as water gas plant in such circumstances is the best of stand-bys.

Many of the largest towns in the United States have for years depended on coke oven supplies of gas, and these are found cheap and convenient. In 1921, the Peoples' Gas Company in Chicago built a new gas-works and installed 105 Koppers ovens to carbonize 1830 tons of coal a day, while they are purchasing a very large quantity of surplus gas from a neighbouring Coke Oven Company. The New York Consolidated Gas Company have installed 74 coke ovens, each measuring 40 ft. 8 in. by 13 ft. by 14 in. average width, to carbonize 1560 tons of coal a day. Gas Companies in Providence, R.I., Terre Haute, Ind., St. Louis, Mo., Indianapolis, Ind., Milwaukee, Wis., Chester, Pa., have for many years employed large ovens on a considerable scale for making gas. There is, in fact, a general consensus of opinion in the United States that the large oven is suitable for gas-works from the point of view of capital cost, results in quantity and quality of gas, coke, tar, and ammonia, labour cost, and maintenance charges.

The general arrangement of the machinery for operating large ovens is similar to that shown in fig. 4; the lay-out also being on the lines set out in fig. 3.

The operation of the large horizontal oven is similar to that described above in connection with the intermediate size of oven, but generally with the large oven the coal to be used is first carefully prepared. This preparation entails, first, its passage through a breaker and its separation from any foreign matter—*i.e.*, iron, wood, or hard mineral material. This is usually carried out in a "Bradford" breaker. Secondly, if two coals are to be blended, as is generally the case, each is first pulverized and then blended with the other coal by means of a belt system which enables an intimate mixture to be formed.

The coal mixture is delivered to an overhead hopper above the ovens, and is then fed into the travelling coal-wagon, which charges the ovens with a weighed quantity, on a time schedule, through openings in the tops of the ovens, while simultaneously the pushing machine reciprocates a levelling ram through doors in the top of the ovens, to level the charge.

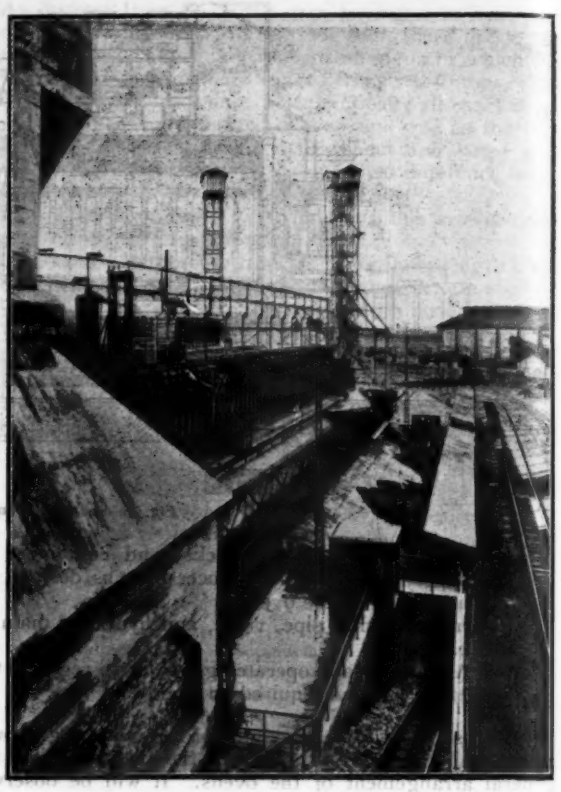

Fig. 5.—Discharge Side of Ovens (Koppers Company, Germany).

The handling of the coke upon its discharge from the ovens is shown in figs. 5 and 6. In the former the coke is being discharged into a wagon, which will then be removed to the quenching spray at the end of the bench, and afterwards brought to the sloping coke wharf, and tipped. An essential feature of importance is the quenching of the coke while still in the coke wagon, and then, after draining excess water, its discharge upon an inclined floor known as the coke wharf, where, lying in a comparatively thin layer, it cools, and can be re-quenched if any fire develops, prior to its removal through doors, or often over a roller feeder shown in fig. 6, on to a rubber belt conveyor.

This system of first quenching, secondly discharging, and thirdly cooling is superior to any arrangement in which the coke is quenched directly and finally on a sloping floor, as the nature of coke is such that, if quenched finally *en masse*, some of it must be either over-quenched

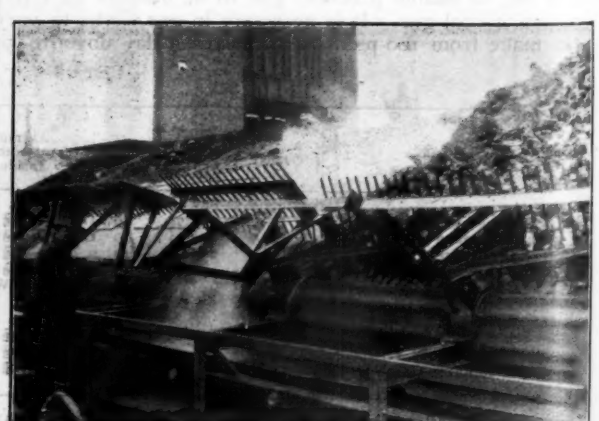

Fig. 6.—Coke Wharf with Door opened and Roll Feeder at work Delivering Coke to Belt Conveyor.

or under-quenched, and in the latter case combustion takes place, both wasting and deteriorating the coke.

UNIFORM CARBONIZATION OF THE CHARGE.

For many years it has been a problem to carbonize the complete charge in an oven in such a manner that, while all the coal is properly carbonized, as little as possible of the coke has been over-carbonized. The narrow oven, as now invariably used in the United States, certainly has substantial advantages in these respects.

A few years ago Becker, of the Koppers Company (U.S.A.), introduced an important change in the heating of the ovens by taking the heating gases upwards vertically as before, and then over the oven, and downwards in a similar number of vertical flues, as shown in figs. 7, 8, 9, 10, and 11.

By the old means the single horizontal flue was an awkward neck of the bottle, and interfered materially with the design of the large oven, and also prevented the complete and speedy carbonizing of the coal at the top of the oven. The new design appears to be an unqualified success, and has already been adopted in numerous installations. It is shown in figs. 7, 8, and 9.

The internal temperature of the charge in an oven is shown in figs. 12 and 13. Fig. 12 represents the conditions in the old type of American Koppers oven, and in many other types, with which it was necessary to work appreciably longer coking times if the coke was to be uniformly carbonized. Fig. 13 shows the conditions in the new type of Koppers Becker* oven when working on 11-hour carbonizing periods.

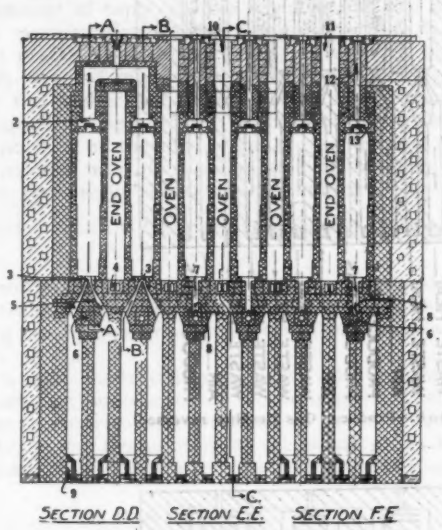

Fig. 7.—Cross Section through Becker Oven.

OVEN TEMPERATURES.

The temperatures worked in the oven flues at the point

* The first Becker oven installation to be built in England is now being erected by the Woodall-Duckham Company.

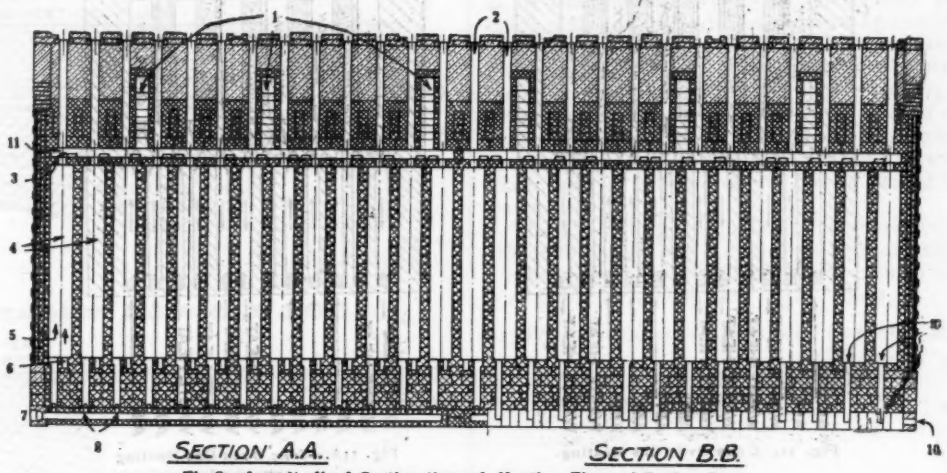

Fig 8.—Longitudinal Section through Heating Flues of Becker Oven.

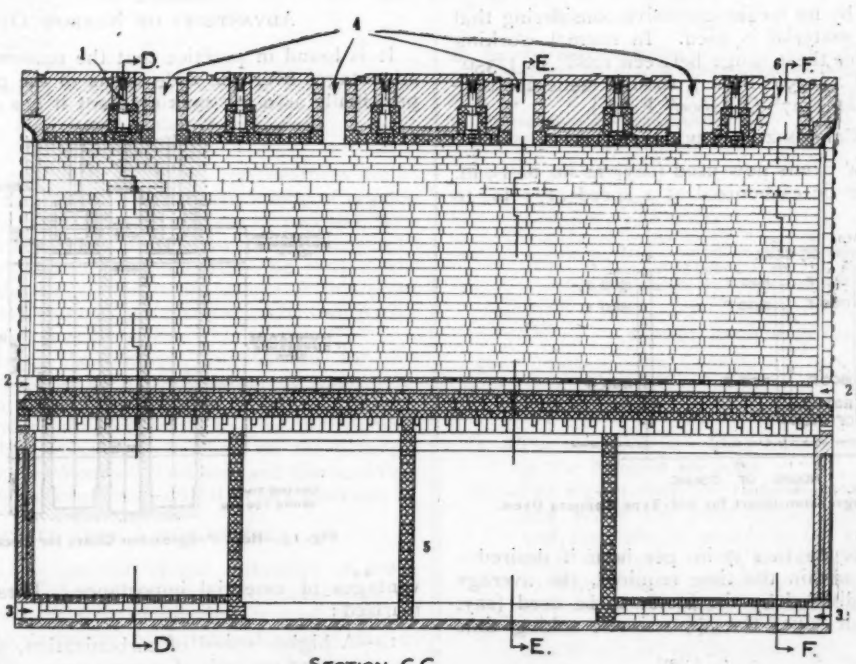

Fig. 9.—Longitudinal Cross Section through Becker Oven.

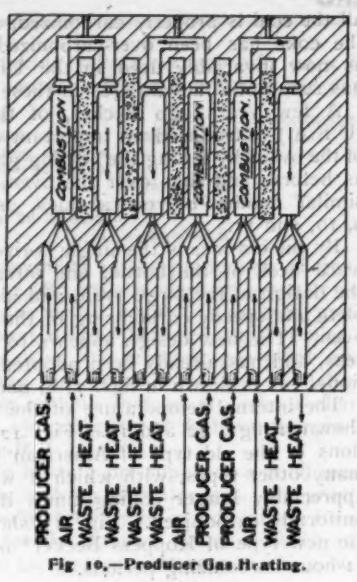

Fig 10.—Producer Gas Heating.

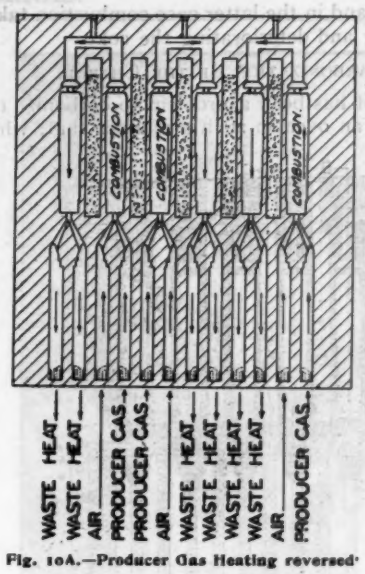

Fig. 10A.—Producer Gas Heating reversed.

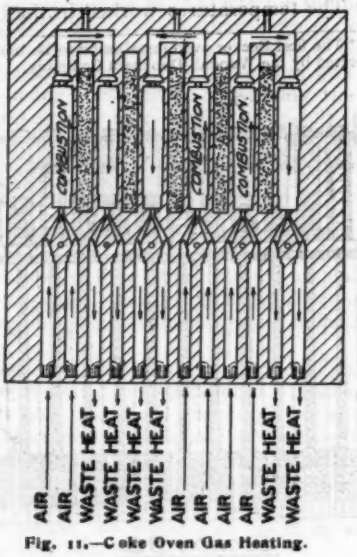

Fig. 11.—Coke Oven Gas Heating.

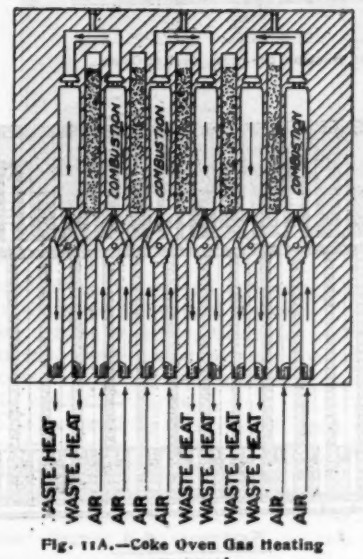

Fig. 11A.—Coke Oven Gas Heating reversed.

of combustion are by no means excessive considering that high grade silica material is used. In normal working in the United States these range between 1288° C. (2350° Fahr.) and 1399° C. (2550° Fahr.), though some use temperatures as high as 1427° C. (2600° Fahr.).

Carbonizing Periods.

With the narrow ovens now used (say, 12 in. to 15 in. wide), charges can be carbonized at a speed of 1 in. to

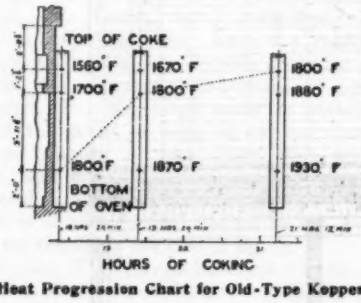

Fig. 12.—Heat Progression Chart for Old-Type Koppers Oven.

1·2 in. per hour, or up to 1·37 in. per hour if desired—that is to say, to obtain the time required, the average width of oven is divided by the factor to be used (say, 1·1), and the result gives the approximate coking time required.

Thus, $\frac{13{\cdot}5 \text{ in. average width of oven}}{1{\cdot}1 \text{ in. speed of coking}} = 12{\cdot}2 \text{ hours.}$

Advantages of Narrow Ovens.

It is found in practice that the narrow oven has many advantages over the wide ovens of the past, and for use principally as a gas-making plant it has very marked ad-

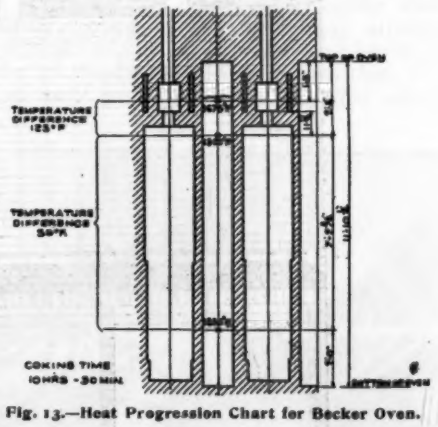

Fig. 13.—Heat Progression Chart for Becker Oven.

vantages of essential importance. These may be summarized:

1.—A higher speed of carbonization, and much larger output per unit of ground area.

2.—The coke contains less sponge, and is more uniform in quality.

3.—Higher production of gas, tar, ammonia, and benzole per ton of coal.
4.—Less fuel required.

OVEN TAPER.

The amount of taper used in constructing the modern oven is particularly worthy of notice. In Koppers (U.S.A.) practice the 40 ft. ovens are only 1½ in., and the 20 ft. ovens ¾ in., wider on the coke discharge side than on the pusher side; these tapers being much less than originally employed. The problem of coking the thicker portion of the charge in the same time as the thinner portion was always a matter of much difficulty, and is by this means substantially minimized.

TRANSFERENCE OF HEAT TO THE CHARGE AND FROM WASTE GASES TO AIR.

It is not generally realized how great is the proportion of heat transferred to the ovens in the upward passage of heating gases in comparison with that from the downward passage.

This is well illustrated in fig. 14. This diagram also emphasizes the importance of recovering the waste heat in the regenerator, which with modern ovens is done very efficiently, as the temperature of the waste gases leaving the regenerators commonly varies from about 193° to

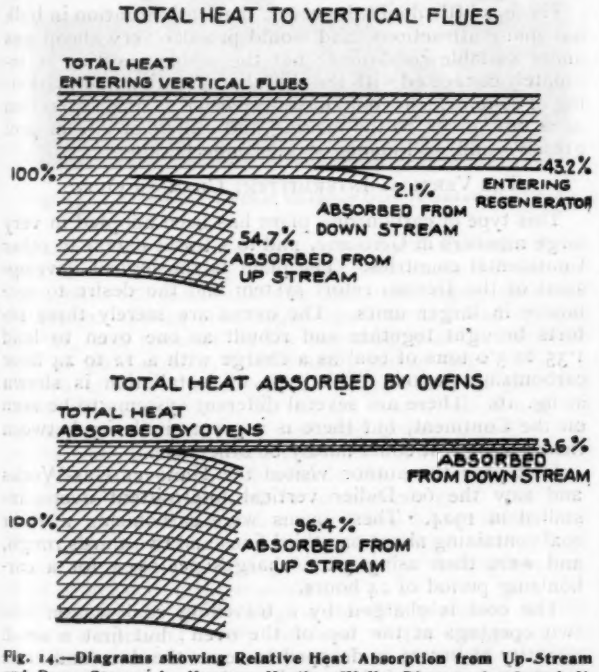
TOTAL HEAT TO VERTICAL FLUES
TOTAL HEAT ENTERING VERTICAL FLUES
100%
43.2% ENTERING REGENERATOR
2.1% ABSORBED FROM DOWN STREAM
54.7% ABSORBED FROM UP STREAM
TOTAL HEAT ABSORBED BY OVENS
TOTAL HEAT ABSORBED BY OVENS
3.6% ABSORBED FROM DOWN STREAM
100%
96.4% ABSORBED FROM UP STREAM

Fig. 14.—Diagrams showing Relative Heat Absorption from Up-Stream and Down-Stream in Koppers Heating Wall. Diagram by Joseph V. Ackeren. (From Porter on Coal Carbonization.)

288° C. (380° to 550° Fahr.). These temperatures are in accordance with the author's own observations of regenerators working on the Siemens' principle of reversal, with both ovens and retorts. The Siemens' system appears to be the best means of efficiently transferring the heat of the waste gases to the air, as the temperatures at this point in ovens and retort settings are too low to be thoroughly transmitted through fireclay walls.

The alternative to the Siemens' regenerator for this purpose would seem to be a combination of the waste-heat boiler and a small recuperator large enough merely to heat the secondary air sufficiently to give the required temperature in the combustion chamber, on the principle now employed by the Woodall-Duckham and Glover-West Companies in their continuous vertical retort systems.

RESULTS FROM LARGE OVENS.

In considering the question of the suitability of ovens for gas-works, the author gives below the actual working figures during the year 1919 of a large plant of Wilputte ovens installed to carbonize 1300 tons of coal a day in Hamilton, Canada.

The Wilputte* oven, as installed at Consett, Co. Durham, and in a number of works in the United States and

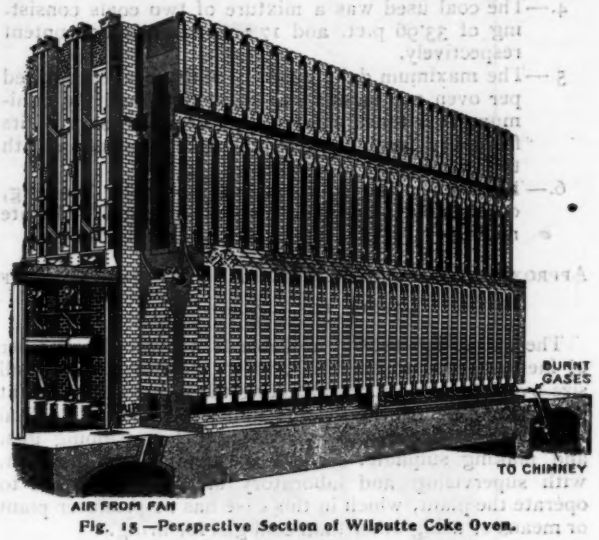

Fig. 15.—Perspective Section of Wilputte Coke Oven.

Canada, is shown in fig. 15. The author has no later figures of this plant, which is, however, on modern lines, and is generally similar and of the same design substantially as those installed a few years ago at the Consett Iron Company's works. The fact that the Consett plant is, or was, the only American type of oven plant in England influenced the inclusion of these figures in this paper.

This plant was installed to make metallurgical coke primarily, but the only essential difference between such a plant and one specially designed for a large gas-works would be the provision in the latter case of a mechanical producer plant, and the division of the regenerators into two sections, with the necessary fittings to enable the producer gas, as well as the air, to be heated by the waste gases.

The gas is high in quality; and if reduced 10 p.ct. by the addition of producer gas—as is frequently done in the United States—it would still bear comparison with coal gas as ordinarily supplied in this country.

80 *Wilputte Ovens at Hamilton, Canada. Results for the Year* 1919.

Monthly Analyses of Coal Used.

	P.Ct.
Vol. comb. matter	30·89
Fixed carbon	59 98
Ash	9·12
	99·99
Moisture	3·1

No. of ovens in operation	80 throughout
Coking time varied from 16 hours 16 mins. to 23 hours 55 mins.	
Average charge of coal	11·48 tons (11·14 on dry basis)
Average total coke and breeze made	74·42 p.ct. of coal
Breeze varied from	9·1 to 3·92 p.ct. of coal
Average gas made	11,600 c.ft. per ton of dry coal
,, B.Th.U. per c.ft.	592
,, therms per ton of coal	68·6
,, gas used for heating ovens	35·6 p.ct. of make
,, heat required to carbonize 1 lb. of coal.	1083 B.Th.U.
,, No. of men per 24 hours	146
,, sulphate made per ton of dry coal	28·2 lbs.
,, tar ,, ,, ,, ,,	9·8 gallons

Average Analysis of Gas.

CO_2.	C_nH_m.	O_2.	CO.	H_2.	CH_4.	N_2.
2·9	3·98	0·35	4·29	52·7	30·4	5·43

As regards the above figures, it should be explained that:

1.—The variation in coking time is due to the variation in the demand for coke.
2.—The higher than the theoretical yield of coke, over and above the fixed carbon and ash in the coal and the volatile matter in the coke, is in accordance with coke oven practice, and is due chiefly to deposition of carbon by decomposition of hydrocarbons in the gases and tar vapours.
3.—The monthly average of breeze made over the year was 6·02 p.ct. on the coal used.

* The Coppée Company (Great Britain) are the English builders of the Wilputte oven.

4.—The coal used was a mixture of two coals consisting of 33·96 p.ct. and 17·12 p.ct. volatile content respectively.
5.—The maximum daily quantity of dry coal carbonized per oven per month was 16·22 tons, and the minimum 10·9 tons, which gives some measure of its flexibility for both gas and coke production with the entire plant at work.
6.—The men employed cover coal and coke handling, carbonizing, benzole production, and sulphate manufacture—*i.e.*, up to dry purification of gas.

Approximate American Costs of Large Ovens and of Labour for Operation.

The author has set out in Table II. the varying number of men required to operate, and the capital cost of, full size ovens; these figures including the entire cost of plant (other than electric generators and water pumps) to deal with coal and coke and all bye-products, stripping gas, and making sulphate. There are detailed all the men, with supervising and laboratory staff, &c., needed to operate the plant, which in this case has no producer plant or means of using other than coal gas for firing.

These figures are based upon:

1.—American costs of construction, materials, and labour.
2.—Labour cost of 2s. 5·7d. per hour (including supervision).
3.—Three shifts of eight hours each.
4.—Ovens measuring 42 ft. 1½ in. over-all of brickwork by 13 ft. high by 14 in. average width, with capacity of 11·15 tons of coal.
5.—12-hour charges.
6.—Coal containing 30 p.ct. of volatile matter and 9 p.ct. of ash.
7.—Coke yield, 74 p.ct. of coal.
8.—Surplus gas at 7300 c.ft. per ton, and a total yield of 11,770 of 575 B.Th.U.
9.—The materials and supplies item includes all materials required for operation, repairs, and maintenance; for sulphuric acid, caustic soda, lime, wash oil, lubricants, &c.; also for water, power, steam, and laboratory.
10.—The plant working at 100 p.ct. capacity throughout the year, which means that allowances must be made to suit the figures to other varying conditions.

As regards the figures in Table II., these are included with the object of showing in the first place the relative cheapness, both in initial outlay and working costs, of the larger as compared with the smaller plants. The differences, as will be seen, are very substantial. Secondly, the figures emphasize the small amount of labour required to operate a plant carbonizing coal in bulk on a large scale. These figures were furnished by a well-known firm of oven builders in the United States, and cannot be personally vouched for by the author.

Good as these results would seem to be, they were surpassed in some respects by a works which the author visited in Germany, and which had a battery of 70 large coke ovens, employing 75 men in all, this number being sufficient to operate ovens and run the entire works, including repairs and maintenance, and the making of sulphate and the extraction of benzole. There were, however, no producer plant, boilers, or electrical generating plant on the works. These ovens, of the new Otto design, carbonized charges of 13·6 tons in 17 to 24 hours, according to market requirements. This works carbonized upwards of 36,000 tons of coal per month, all of which was handled by one set of oven machinery and one gang of men per shift, which indicates the high capacity of modern oven plant, and its suitability, in many respects, for making gas on the large scale.

The impression formed in visiting these large plants obtaining substantially the same yields as are obtained in retort plant is that, in using such small units as we almost invariably do in our large gas-works, we are losing much of the advantage which should accrue from mere size. Our electrical competitors are generating their commodity substantially cheaper in the very large stations than in small ones; and it would seem as though the same relative advantage should be obtained in the very large gas-works.

The author had intended to prepare an estimate of the cost of construction and operation of large horizontal ovens under English conditions, and to form an approximate idea of the cost of making gas by such means. It seemed, however, that such an estimate would have to embrace assumed figures for some of the most important items (local conditions being unknown), and so would introduce too large an element of unreliability. The estimate is accordingly omitted.

There is little doubt, however, that carbonization in bulk has many attractions, and would produce very cheap gas under suitable conditions; but the whole question is intimately connected with the skilful preparation and marketing of coke, which would have to receive as much attention as is now given to the making and selling of gas in progressive and well-managed gas undertakings.

The Vertical Intermittent Chamber Oven.

This type of carbonizing plant has been adopted in very large numbers in Germany, and to a lesser extent in other Continental countries. The plant is the logical development of the Dessau retort system and the desire to carbonize in larger units. The ovens are merely three retorts brought together and rebuilt as one oven to hold 1·35 to 5·0 tons of coal as a charge with a 12 to 24 hour carbonizing period. This type of installation is shown in fig. 16. There are several different systems to be seen on the Continent, but there is a great similarity between them; in fact, it could hardly be otherwise.

Last year the author visited the Hanover Gas-Works and saw the 60 Didier vertical intermittent ovens installed in 1924. These ovens were carbonizing a Ruhr coal containing about one-third fines and two-thirds rough, and were then using 5-ton charges per oven for a carbonizing period of 24 hours.

The coal is charged by a travelling coal wagon into two openings at the top of the oven; but first a small quantity of breeze is dropped to cover the door and raise the bottom level of the coal into the heating zone. The coke is discharged by opening the door at the bottom of the oven; this door being mechanically operated by a rack and pinion, the rack being reciprocated by a hydraulic ram. The door is closed by the reverse movement; and it is then necessary to tighten the door on its face by means of eccentric fasteners and hand levers. The hot coke is dropped into a bogie, which is mechanically propelled to the end of the bench, where it is quenched and tipped according to local requirements.

At Hanover the coke receiving wagon was fitted with

Table II.—*Estimated Costs of Construction and Operation of Ovens in the United States.*

Number of Ovens	30	45	90*	135	180
Coal carbonized per day . . . tons	670	1,000	2,010	3,015	4,020
Coke produced ,, . . . ,,	495	743	1,486	2,230	2,970
Surplus gas ,, . . . 1000 c.f	4,875	7,312	14,625	21,937	29,250
Estimated cost of plant . . . £	412,000	484,500	773,000	990,000	1,155,000
Capital cost per ton coal daily capacity . . . £	548	430	343	293	256
Number of men employed . . .	140	140	170	240	280
Daily labour cost . . . £	138	138	168	237	277
Annual fixed charges at 12 p.ct. . . . £	49,500	58,100	92,800	118,700	138,500
Coal carbonized annually . . . tons	244,000	361,500	733,000	1,100,000	1,466,000
Coke produced ,, . . . ,,	181,000	271,000	542,000	813,000	1,085,000
Materials and supplies per ton of coal (see details below) d.	49·2	46·8	45·6	44·4	42·7
Labour cost per ton of coal . . . d.	49·5	33·1	20·0	18·8	16·4
Labour cost, calculated on an English basis of 12s. a day d.	28·1	18·7	11·3	10·6	9·3

* The maximum number of ovens that can be operated by one set of oven machinery and one gang of men.

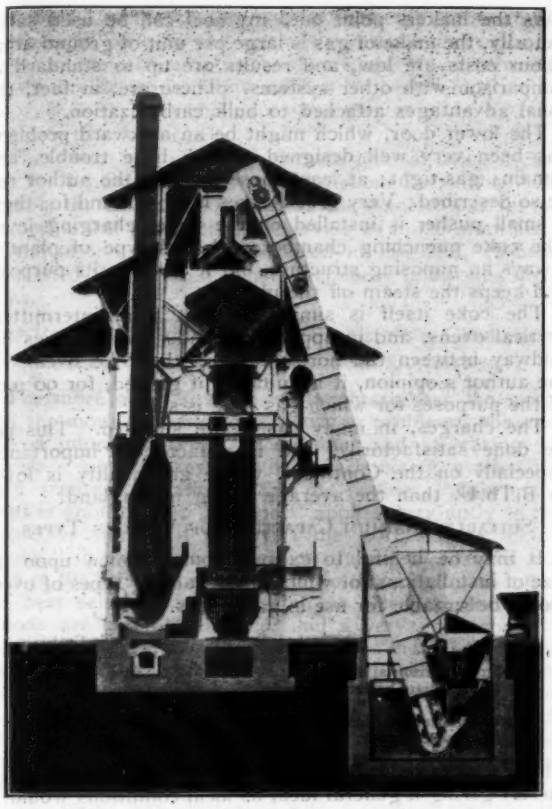

Fig. 16.—Intermittent Vertical Chamber Oven (Woodall-Duckham).

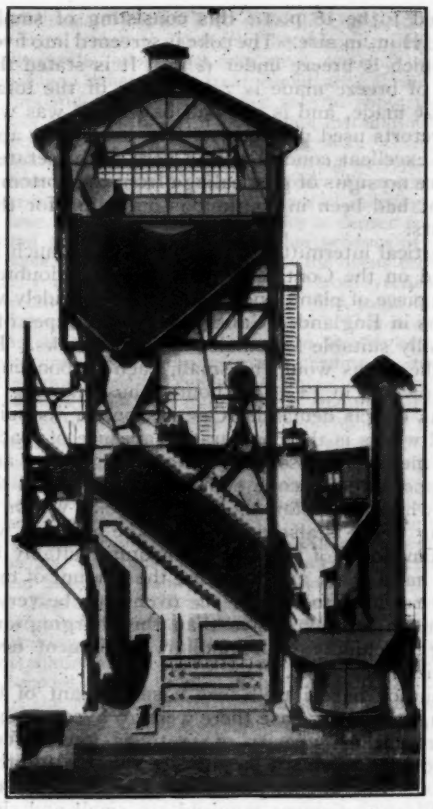

Fig. 17.—Inclined Chamber Oven (Woodall-Duckham).

a water jacket connected by small holes to the coke chamber; this water being converted into steam by the hot coke, with the result that the coke was largely quenched by steam. These coke bogies were then picked up by a telpher, and removed to the screening plant. The coke was of good quality, a little hard, and of large size.

Two attached producers of considerable height, and fitted with step grates, served six ovens, which had the appearance of being very well and evenly heated. The ovens were being worked under a vacuum of ¼ in.; and no gas leaks were visible while the author was there. The installation appeared to have many good qualities; but the object of the author's visit was to see some other plant, and he did not pay the close attention to it that he would have done had he gone there for the express purpose of inspecting these ovens.

The problem of making a durable plant is, in the author's opinion, chiefly confined to the design of the bottom door and its maintenance in a gas-tight condition for a sufficient period of years. It will be appreciated that the gas must find its way out of the oven without causing any appreciable pressure to be thrown on the bottom door, as leaks at that point can be very troublesome. A brief explanation will suffice to show the importance of this. In this system the charge of coke is dropped hot into a bogie underneath; and this is then in most cases drawn away to the end of the bench for quenching. Consequently, should there be any gas leaks in any of the doors under which the bogie passes, these must inevitably light up, and eventually cause much damage to the doors and bottom ironwork.

Anyone who, like the author, has seen the entire bottom ironwork of an installation of Dessau retorts alight from end to end after the passing of the bogie of hot coke, will never forget it, and will appreciate the importance of keeping the bottom doors gas-tight at all costs. This system has so many good features that one potential weak spot—weak only if neglected—will not hinder its progress. The possibilities of mischief in this direction can be minimized by arranging for the removal of the coke by some alternative means. In a few of these installations it is taken out in a right-angled direction to the line of the bench, and so the hot coke does not have to pass under the other ovens.

The discharging and the charging of the ovens are exceptionally simple, and necessitate the minimum amount of labour. There is no problem in heating the ovens properly.

The advantages of the vertical intermittent oven system are clearly substantial:

1. It is suitable for any kind of coal.
2. It requires a minimum of ground area.
3. It accommodates itself to the sites of stop-end horizontal retort houses.
4. It can be operated with a minimum of labour, and if desired on two 8-hour shifts per 24 hours.
5. The charge can be steamed satisfactorily.
6. The coke will bear favourable comparison with that produced from the same coal in other systems, and will contain a minimum of breeze.
7. It does, and should, produce satisfactory yields of gas, coke, tar, and ammonia from the coal.
8. It is adaptable to the smaller works—and on the Continent there are many works with installations making from 100,000 to 750,000 c.ft. per 24 hours—while the small cost of plant to operate the ovens is a distinct advantage.
9. The capital cost of the plant and its maintenance costs should compare well with other systems.

Since writing the above, the author has had the opportunity of visiting the Mannheim Gas-Works, where he saw two types of intermittent vertical ovens, one of the Pintsch-Otto, and one of the Didier system; and these are certainly deserving of some special mention.

Both systems have a general similarity in design, and are different only in detail. In each case there were 30 ovens at work. The charge per oven is 2½ tons for 12 to 24 hours' duration, according to gas demand. Steaming for the last 3 hours of the charge is practised, and the quality of gas made varied from 517 to 550 B.Th.U. per c.ft. The labour required is 9 men per 24 hours for 30 ovens, this covering the elevation of the coal and the delivering of coke to the screening plant; but as there is an outside mechanical producer plant (Koppers type) heating the installations, it is necessary to add a further 2 men per 30 ovens to cover the labour requirements on this work.

Each installation makes about 1,850,000 c.ft. of gas per 24 hours, and therefore the make per man employed per day works out to 168,100 c.ft. The fuel consumption

was stated to be 18 p.ct., this consisting of small coke from ⅛ to ¾ in. in size. The coke is screened into five sizes, one of which is breeze under ⅛ in. It is stated that the quantity of breeze made is 7 to 8 p.ct. of the total coke and breeze made, and is one-half of what it was with the Dessau retorts used previously. The oven plant appeared to be in excellent condition, and very well operated, and there were no signs of gas leakage from the bottom doors. One plant had been in continuous operation for the past four years.

The vertical intermittent oven, as used so much in Germany and on the Continent generally, is undoubtedly an excellent piece of plant, and is likely to suit widely varying conditions in England. Unlike most other types of plant, it is equally suitable for small and large works. For the former the ovens would be small, each carbonizing (say) 22 cwt. of coal in 12 to 24 hours, thus allowing for the variations of gas demand. One reason for its suitability for small works is the comparative absence of machinery, it being merely necessary to elevate the coal to an overhead hopper and the coke sufficiently high to fill the producers, while a capstan to haul the coke wagon to the quenching tower is also desirable. The gear for working the bottom doors of the ovens can quite suitably be operated by hand gear; and therefore the amount of mechanical plant required to operate the ovens can be very small, and is much less expensive than the charging and discharging machinery with auxiliary equipment necessary with horizontal retorts.

The author has himself seen a small plant of this description, and in this case there were 10 ovens with a total daily carbonizing capacity of 11 to 22 tons of coal. It looked to the author to be entirely suitable for that size of works. For the larger works the mechanical plant and auxiliary equipment required are small and simple in comparison with other systems.

The Inclined Chamber Oven.

This type of carbonizing plant has many advocates on the Continent. A sectional view is shown in fig. 17.

Large installations of this type are to be seen in gas-works in the following important Continental cities.

Paris, where there are plants with a total capacity of	26·8 million c.ft. per diem.
Berlin, " " " " " " " "	8·6 million c.ft. per diem.
Hamburg, " " " " " " " "	13·4 million c.ft. per diem.
Munich, " " " " " " " "	6·7 million c.ft. per diem.
Rome, " " " " " " " "	6·07 million c.ft. per diem.

There are eleven installations with a daily capacity under half-a-million, twelve under one and over half-a-million, and sixteen over one million c.ft. Accordingly, this system can be said to have claims for all sizes of gas-works.

Its adoption in such important cities indicates that it is worthy of much more consideration than it has hitherto received by gas engineers in this country and in the United States, for, except at Darwen, the author is not aware that there are any inclined chambers in either of these countries. The author has seen these installations on several occasions on the Continent, and on each occasion the plants have been working well, with no obvious drawback so far as he could see.

During a recent visit to the Continent he had the opportunity of seeing a large installation of this type of plant in Paris. At this works there are 162 ovens, each with a coal carbonizing capacity of 5 tons 14 cwt. per 24 hours. These ovens are charged for 24 hours, and each section of 54 ovens is operated by one gang of men working on one shift per 24 hours; 25 men being sufficient to work 54 ovens per 24 hours. This is roughly equivalent to 135,000 c.ft. of gas per man per day. The fuel consumption in built-in producers was stated to be 16 p.ct.

The author was impressed with the durability of the plant, as he was informed that all these ovens had been working for varying periods from 6 to nearly 9 years continuously. At this works the variation in gas demand is taken up by horizontal retorts and water gas plant; this, of course, having an important bearing upon the life of the oven plant.

As the makers point out, any coal can be used satisfactorily, the make of gas is large per unit of ground area, labour costs are low, and results are up to standard in comparison with other systems. There are, in fact, the usual advantages attached to bulk carbonization.

The lower door, which might be an awkward problem, has been very well designed, causes little trouble, and remains gas-tight; at least those seen by the author can be so described. Very few charges hang-up, and for these a small pusher is installed on the upper charging level. The coke quenching chamber with this type of plant is always an imposing structure, but it answers its purpose, and keeps the steam off the plant.

The coke itself is similar to that from intermittent vertical ovens, and in appearance and characteristics lies midway between the horizontal and the coke oven. In the author's opinion, it is suitable, if graded, for 90 p.ct. of the purposes for which gas coke is sold.

The charges, in many cases, are steamed. This can be done satisfactorily, and is a factor of importance, especially on the Continent, where gas quality is lower in B.Th.U. than the average ruling in England.

Suitable Minimum Capacities of Various Types.

It may be helpful to express some opinion upon the size of installations for which these varying types of ovens would be suitable for use in gas-works.

	Daily Coal Carbonizing Capacity.
Small horizontal ovens	from 23 tons
Intermediate horizontal ovens	" 100 "
Large "	" 700 "
Intermittent vertical "	" 10 "
Inclined chamber "	" 60 "

These figures must be taken with considerable reserve as merely giving a general idea, as local conditions would be calculated to affect materially any preconceived conclusions in regard to the suitable capacities of plant of the various types discussed in this paper.

Ovens in Germany.

A recent trip to Germany to see a few of the latest oven installations confirmed the author's view that Germany was not only designing and building coke ovens as good as, and possibly better than, any others in the world, but was also adopting ovens of various types in wholesale fashion for their gas-works. The German gas engineer evidently considers that the oven—it may be horizontal, inclined, or vertical intermittent or continuous—is the most suitable type of carbonizing plant for making gas, as large numbers of the old and most of the new plants appear to be ovens.

Intense activity in the building of ovens is very noticeable; and the two large firms, Koppers and Otto, have orders for over 2000 large horizontal ovens on their books. This is an immense number, which is better realized when it is stated that these new ovens would be able to carbonize at least 70 p.ct. of all the coal carbonized in British gas-works. That such ovens will manufacture coke, and incidentally gas, far cheaper than the old ovens they displace, is self-evidence to anyone who studies the question and appreciates the very great progress which has been made in the design, construction, and operation of these new ovens.

The author saw the Otto ovens at the Rotterdam Gas-Works, and the Koppers ovens at Dusseldorf Gas-Works, both of the horizontal type; and these visits merely confirmed the favourable opinions previously held in regard to the suitability of large horizontal ovens for large gas-works.

There is one further point worthy of special mention. One large firm of horizontal oven builders told the author that they were always prepared to contract over a period of 10 years to undertake the entire repairs and renewals of the oven brickwork for one penny per ton of coal carbonized. The provision of clean coal gas or producer gas would undoubtedly be a *sine quâ non* of such a contract.

The Use of Mechanical Producers.

For the various types of oven installations in the United States and Germany, there is a considerable use of mechanical producers to supply the heating gas. In nearly all cases the producer gas is cooled and washed, of which heat a good deal is recovered, and consequently

the control of the heating can be by metal cocks, and no damage is done to the settings by dust—a destructive agent where refractory materials are concerned. Further, all the breeze made, supplemented by small coke, can be the fuel used; this being an economy, as giving a large quantity of coke for sale.

That there is a very considerable gain in using a clean gas for heating ovens leaves little room for doubt. The author, therefore, would express the opinion that the use of mechanical producers is deserving of much more attention than it has hitherto received in England, as being calculated to lead to a general economy in various directions.

The Essential Importance of Selecting a Carbonizing System Suitable to the Local Conditions.

The more one visits gas-works throughout the world, and the more one studies carbonizing problems, the more one is impressed with the essential and increasing importance of selecting the best carbonizing system for each separate situation. The old saying, "One man's meat is another man's poison," applies very aptly to this particular matter, if we insert the word "gas" before "man" in each case. Occasionally one sees a bad mistake in the selection of plant, and oftentimes by no means the best selection is made; but as often the local conditions are carefully studied, and a very good choice is made. Of the latter a good example is that of the Ramsgate Corporation, where the first installation of vertical intermittent chambers in this country has been built and put to work with successful results. In this case the site and local conditions could not have been more favourable to this system, while being in some respects distinctly unfavourable to other systems.

[The paper was illustrated with a considerable number of lantern slides showing general views and important features of the various ovens described.]

Discussion.

The President: Mr. Gill has dealt with a most fascinating subject in a masterly manner; and I trust the paper will produce the discussion it deserves. A number of important points have been emphasized by Mr. Gill; and the question of carbonizing in bulk is undoubtedly most fascinating to all of us. I think it was the late Sir William Ramsay who made the statement that the day would come when the whole of the coal would be consumed in the measures, and that we should tap energy at the pit bank. We may have to wait a long time for that; but there is apparently a midway house, as suggested by Mr. Gill. To my mind, there are three important points involved. One is the question of the quality of the coke for domestic use; and that is a point which, although of great importance, is not, in my opinion, insurmountable as far as English practice is concerned. The second point is with regard to the use of mechanical producers, and the statement made by Mr. Gill that they are able to consume very large quantities of fine coke. I have inspected a number of these mechanical producers on the Continent, and in every case, without a single exception, I found they were screening-out the finest dust, although we were told that in every instance they would burn anything. When I drew the attention of the engineers to the fact that they were screening-out the finest dust from the breeze, I never obtained an explanation. All I got was the usual emphatic shrug of the shoulders. I agree that a great deal of the difficulty which has followed the introduction of mechanical producers is done away with by the washing of the gas; but what effect that really has on the amount of fuel required for heating the ovens, I do not quite know. The question of over-carbonizing the charge is another rather important point; and I do not see how they get over it in the particular settings described by Mr. Gill, in which the direction of heating of the gases is first up one side and then down the other. One might have been inclined to imagine that the higher heat on one side would tend to shorten the life. Mr. Gill, however, has immediately answered this by pointing to the long life of these ovens; and that, to my mind, is possibly the most important matter of all. There are many interesting points in this valuable paper, which is now open for discussion. I see many here who have had experience of ovens; and I wonder whether Mr. Glover will be good enough to "open the ball" for us. I remember an interesting visit to his works some years ago.

Mr. Thomas Glover (Norwich): This is a fascinating paper, as the President has said; but our efforts in England recently have gone in other directions for the most part. The competition, in my opinion, is going to be between bulk carbonization and continuous carbonization in retorts of increasing size. We are so satisfied with the results we obtain from continuous carbonization—as to capital cost, reliability, and reduced cost of upkeep—that I think the day may be delayed when we shall, on a large scale, adopt the coke oven system, in which at one time I and others had great confidence. I did make an attempt, as you know, and I was able to show the visiting members of the Institution in 1909 some installations of ovens heated with producer gas and charged with a De Brouwer machine of special design; the charge being pushed-out with a De Brouwer pusher, electrically operated. This system of carbonization was developed for the purpose of meeting a demand at that time, and which still exists, for a denser coke for the nurseryman growing tomatoes and other produce of that kind. These people like the dense coke which the ovens produce; and now that I am making coke entirely from verticals, I am bound to confess quite candidly that I find some difficulty in keeping my market with the nurserymen. This is accentuated by the fact that the coke oven people in Nottinghamshire and Derbyshire are crushing the coke and grading it, and offering it to nurserymen and for central heating. They are in actual and real competition with us. Funnily enough—and it is interesting—the vertical coke has found new markets which have compensated for the loss of some of the old ones. We know that vertical coke ignites more readily, and satisfies the demands of the domestic and other users; and we are selling more coke to-day than ever we did, in spite of the fact that the nurserymen have to some extent left us. If you want to make coke for the nurseryman, and if you want to compete with the colliery people, you must have some system of carbonizing in bulk. You have had some fine illustrations given to you; and you have heard Mr. Gill speak of the great movement in America and in Germany. I shall be surprised if some of the big undertakings of the country do not adopt, at a very early stage, installations such as have been shown us this morning, for the purpose, at all events, of making a trial and a comparison of the relative merits of carbonizing in bulk as compared with the continuous system of carbonization which is working so well in this country, and is giving us such great satisfaction. I may say quite candidly that we gave up the chambers because of the increasing demand made on the retort house in which they were installed; and it was necessary to have a uniform system of carbonization. Nevertheless, we did learn some very useful lessons. We learned to fill our ordinary section of retorts full, and gained thereby as to the density of the coke, freedom from naphthalene, and freedom from stopped pipes and mains, as well as securing reduced cost of operation. This can be done by anybody, and anybody can have modified carbonization in bulk if he has the right machinery for filling the retorts; and when I say "filling," I mean not three-quarters, but completely, full. You can have carbonization in bulk in your own works pretty quickly, if it has advantages which commend themselves to you.

Mr. H. Chamberlain (Sheffield): My first point is whether Mr. Gill recommends the installation of coke ovens that are heated by a portion of their own gas. The ideal of progress, I believe, is to try to make two blades of grass grow where one grew before, or, to put it in our own language, to use one ton of coal where two tons were used before. The use of coke ovens on a gas-works, where we have twice the amount of coal to handle and twice the amount of coke to store, I do not think is a very good proposition. The alternative is to use the outside producer; but I rather think that Mr. Gill will find, on going into the cost very carefully, that this increases the cost of production, so that it does not compare at all favourably with our present methods of carbonization. Another point is that some of us are labouring under certain difficulties in maintaining a constant quality of gas with different kinds of carbonizing plant; and to add another plant which makes a gas of anything from 530 to 550 B.Th.U., when the ovens are new, is going to increase our difficulties, especially as this new plant is not a flexible one. There are several towns in this country—Sheffield is one of them—which are subject to very violent fluctuations in the load, particularly at week-ends. Our load on a Sunday is 50 p.ct., or less, of the week-day load; and on Saturday it is about 75 p.ct. It is essential that we should have plant which is sufficiently flexible to enable us to reduce the output, or even to shut-down a portion of it, during the week-end. Thus any plant that is not sufficiently flexible to attain these ends must be a very small portion of the total plant installed in the works. The point made by the author as to the summer and winter load is quite a good one; but I want to ask him one question—namely, what is the effect on the quality of the gas of reducing the throughput?

Mr. Thomas Hardie (London): The subject of coke ovens is one of very great interest to me, as it is a matter to which I have given a good deal of consideration. The descriptions in the paper show what is being done in other parts of the world; but in dealing with this matter, we must always consider carefully our own conditions. There are any number of good installations of coke ovens in this country; and we do not require to go abroad to see such plants. We have in this country almost all the systems that have been described, including rubber belts for moving the coke from the ovens, and so on; and I think our coke oven people, although many plants are a little behindhand, are, generally speaking, up to date. In spite of that, gas undertakings have not yet adopted this system,

except in one case, Birmingham, who adopted ovens some time ago, but do not seem to have found it advantageous to extend the plant. All the information we have as to coke ovens relates to their working under coke oven conditions—*i.e.*, continuously from one year's end to another—and that is the first point which makes them not altogether applicable to gas-works. Again, most of the conditions we have been told about relate to heating with coal gas. Therefore all the figures of repairs, maintenance, &c., given to us, have no bearing upon gas-works conditions, because we have not heard of any furnace working with clean gas to bring it into comparison with gas-works practice. There are many things to take into consideration. I am rather surprised to find that the use of breeze and small coke in an outside producer is put down as one of the reasons why they should be adopted with coke oven plants, because I always understood that one of the things about a coke oven was that it created very little dust. To-day, in gas-works, there is scarcely sufficient small coke for the requirements; and I do not think the use of outside producers for the particular purpose to which they are put would appeal very strongly to many gas engineers. Coke dust has a particular use of its own for steam raising, for which it can be employed far more efficiently than in any form of producer. I have been much interested in the descriptions Mr. Gill has given us. He has drawn attention to these processes, and has brought together in one paper a great deal of information that one would have to search for in a great number of other places.

Mr. J. W. McLUSKY (Glasgow): About two years ago a very generous Committee sent me to the United States, when we were studying the problem as to what the plant for the next 10 million c.ft. production in Glasgow would be. I had to look round some dozen places in the wake of Mr. Gill, so that all the questions I wanted to ask had been answered. The great problem then was to put in a plant that would beat anything Glasgow or anybody else had up to that time. I found the engineers in the States as much perturbed about their carbonizing as we are ourselves over here. To judge from Mr. Gill's conclusions, the more one travels, and the more one sees, the less is one inclined to dogmatize about anything. I was amazed in America—one had read about it, but one cannot help expressing amazement—to see such an abundance of the very finest and richest gas coal seams. That is a great problem at once solved for those people. They have got long journeys; but they bring the best coal in big trucks at very low freights, and they get deliveries of the coal they require for special purposes. Then you come to compare that with our position in Glasgow, where we require 3000 tons per day, and cannot get more than 300 or 400 tons of good coking coal. In these circumstances, of course, the situation becomes entirely different. It happened that while I was in the States I had the advantage of discussing with the engineers of two very important gas undertakings which have adopted coke ovens all their figures and the reports for their Boards; and I found the whole thing depended on the quality of the coal, the amount of coke, and the quality of the coke they were going to sell. Now they are developing a fine business in competition with anthracite; and they are making a good coke nut which is selling well and bringing in a good revenue. That problem does not arise with us at the moment. As I said last year, we decided on continuous verticals, followed by intermittent verticals for the small coal; and I believe that in a year's time we shall have a plant which will please the Glasgow Corporation much more than one consisting of coke ovens. I am not going into the question of capital cost, because those costs are very familiar to this audience. I was asked point-blank yesterday why, seeing that I buy coke oven gas at 2·2d. per therm, I do not erect plant and make it for myself. But the people who own the coke ovens in the West of Scotland own the best coking seams. In fact, the coke oven people own the best coal in Scotland; and that is the first handicap. A private man or a corporation who builds coke ovens must go to the people who own the coke ovens for coal. This fact alone rules out the adoption of coke ovens by gas undertakings. That is apart altogether from the cost of carriage of good coking coal to my works. My Committee considered the other day the question of the plant to follow the plant we are now working; and they decided to call a halt, because there are prospects that there will be large installations of coke ovens built in the district. This is why I was asked the question. I cannot see how a Corporation placed as we are can afford to spend money on coke ovens, having in view the competition we shall get. I think we are very much indebted to Mr. Gill for his paper. I would rather call it a lecture than a paper. He has not, of course, lectured us, but he has given us something that is of great interest, and something to which we shall refer and of which we shall make much use. I have also had the pleasure of seeing the plants at Dusseldorf, Rotterdam, Utrecht, and at one or two other interesting places, and was much impressed.

Mr. W. W. TOWNSEND (Colchester): I should like to add my congratulations to Mr. Gill for his paper, and to ask him two questions. The first is whether he can show us a chart from a recording calorimeter indicating the kind of gas as it is made from a typical coke oven plant. I do not mean the average of the gas made, but the gas as made from hour to hour. Then I should like to know—I am not at all clear on the subject—how a waste-heat boiler, properly so-called, can be included in a producer gas plant. Where is the waste of heat? I rather take it from the description that sensible heat is extracted from the producer gas, and is used for raising steam. I submit that this is not waste heat, and therefore it is rather a confusing term to use. Also it seems a pity to cool down the producer gas which has afterwards to be raised to a high temperature in order to heat the settings.

Mr. R. H. RUTHVEN (Ramsgate): I should like to thank Mr. Gill for his kind reference to the Ramsgate Corporation and the choice they made when they decided to put down intermittent vertical chambers. It is always difficult to take a new step and instal the first plant of a particular type; but when we know that many other installations on the Continent are working, and giving enormously satisfactory results, the responsibility is diminished very much. I do not wish to take any time this morning in dealing with our plant, because it is hoped to be possible at some future date to give full details of it. Its capacity is just short of a million cubic feet. Several points have been raised this morning expressing doubts as to certain things. Mr. Chamberlain raised the question of the flexibility of the plant; but so far as these little coke ovens are concerned in conjunction with an ordinary town plant, there is not the slightest difficulty whatever in varying the output of our plant from 900,000 c.ft. or 1,000,000 c.ft. to 600,000 c.ft. or even less than that. The whole operation can take place by varying the carbonizing period. Normally we carbonize on 12-hour periods. The chambers have a capacity of 2·25 tons per 12 hours, and we can vary this to anything we care, reducing the period or reducing the carbonizing temperature. The economy is not affected very much, except that when you are working on other than 12 or 18 hour periods you have to put on another shift of men. Ordinarily our shift has two men only, and the whole of the labour in the chamber house from the entering of the coal into the hoppers until the coke is loaded over the screen is a maximum of six men for the 24 hours. That is when making 1,000,000 c.ft. and carbonizing 67 tons of coal per day. The question of the physical structure of the coke and its suitability for domestic use has been mentioned, and it is a very serious point; but we make a practice of properly grading the coke, and there is no difficulty in finding a market for it. In point of fact, we make a special grade of coke for the "Sentry" type of boiler and for hot water circulating boilers; and it is a very successful fuel indeed. It is about as perfect as a coke or smokeless fuel could be for that purpose.

We have not had a long experience. The plant has been working since Aug. 23 last year; and up to the present we have not had any difficulty such as that mentioned by Mr. Gill with the large doors at the bottom. Moreover, I do not see why we should. The doors never get hot, and are always tight. The pad of breeze is the whole secret; and if it were not there the doors would get hot, and tend to warp. They are very carefully braced, however; and up to the present every door has been absolutely tight. I can show Mr. Townsend a chart from the recording calorimeter; but the result varies with the period of carbonization. If you carbonize steadily for 12 hours you do not get such a big variation as with more shifts. It is our practice, however, to keep one holder filled, and to feed the other for the district; and in that way we get a straight line.

Mr. C. HARRIS (Taunton): Mr. Gill has given us an extremely interesting paper covering practically every type of oven in use to-day; but one statement requires correction. The first large vertical intermittent chamber retorts were erected at Wombwell; and the Taunton installation was erected immediately afterwards—some seven years ago. Mr. Gill's statement as to the long life of these ovens is correct. In the case of Taunton one of the original settings is still working, and will not be renewed for another year, and it is only being wholly renewed because 95 p.ct. silica material is being used in place of fireclay, and the chambers are being made narrower, but with a greater major axis of 8 ft. Our own opinion may be gathered from the fact that an additional setting of six chambers is now being installed, exactly similar to the Ramsgate design; and as the present chambers come to be reset, they will be converted to the narrower type having a maximum width of 12 in., which undoubtedly gives much better results in regard to shorter time of carbonization and consequent lower fuel consumption. Intermittent chambers give one a freer choice of coal than continuous vertical retorts, and can deal with any Kent or Somerset coal. They have the advantage that they produce a good coke from some coals which only give a soft coke in horizontal or continuous vertical retorts; and they certainly make less breeze than the continuous type. There is no difficulty in disposing of the coke if it is properly graded. On the other hand, there is difficulty in discharging some of the chambers towards the end of the life of the setting; and where ground space is valuable, continuous vertical retorts have the advantage of a greater manufacturing capacity for a specified area. In respect of horizontal ovens, a large area is taken up by the discharging ram. As regards uniformity of gas, this is as good as with horizontal retorts, and no difficulty is experienced in maintaining the calorific value within 10 B.Th.U. at the outlet of the holder, which in our particular case is placed on the opposite side to the inlet. Variation in

quality can be obtained by a certain amount of steaming, and in capacity by prolonging the carbonizing period, at the same time reducing the heat in the combustion chamber.

Mr. J. H. BREARLEY (Southport): I do not rise to speak on the paper, but to emphasize the request of the President to the last speaker to speak a little more slowly. It would be very convenient if speakers would speak up clearly and distinctly, so that we can hear. I have not heard a word of what the last two speakers have said; and really I think the time is coming when gas engineers will have to include among their many qualifications some element of elocution.

The PRESIDENT: I sincerely hope that what Mr. Brearley suggests will be done, because we want to understand what the speakers are saying.

Mr. BREARLEY: If the example set by the President were followed, it would make the proceedings much more interesting.

Mr. W. C. JACKSON (Neath): We have heard from Mr. Gill a great deal about the advantages of coke ovens. In South Wales we have run up against coke ovens to a large extent; and some of our brother engineers are in the position of taking a supply of coke oven gas, and distributing it on their districts. It is a pity that some of those gentlemen are not present this morning to speak; but I feel I ought to say something on their behalf. Coke ovens, so far as gas-works are concerned, are, I think, a little late in the day except for very large works away from the coalfields; but it is all a matter of policy on the part of the undertakings and the engineers concerned. Coke ovens have still a lot to do before they are able to produce a gas such as we are able to get from other carbonizing plants to-day. We know very well that, although the average gas taken over the 24 hours may be all right, the gas taken every five minutes, or half-hour by half-hour, is not right. Unless special steps are taken to look after the mixing of the gases, there is bound to be difficulty on the district right away. At present coke ovens in which the double foul main has been introduced certainly help to a great extent, but this does not get over the whole of the trouble. There is the peculiar difficulty of gas mixing to guard against when considering coke ovens.

Then there is the question of coke. Some of us have been in competition with coke-oven coke, and we know that the competition which set off with a big blaze has fallen away. Though perhaps we lost some customers to start with, we have been able to get them back, and have never lost them again—nor is there any chance of losing them again. Personally I think that vertical retort coke, apart from a few very special customers, meets the requirements of the public much better than the denser coke which is produced from the coke ovens. With regard to breeze, I should say the coke oven people are troubled with breeze even more than we are with our old carbonizing plants. I have been over a coke oven in South Wales, and I have seen breeze there which I have not seen in some of our largest gas-works in this country; and the price they have been able to obtain for that breeze has been very low indeed. They accept an even lower price than is paid for the breeze from a small gas-works like mine—when I have any to spare; and usually I have none to spare at all.

The colliery people themselves are looking ahead, and are proposing to put down a still larger number of coke ovens in this country; and I would not be at all surprised to see large financial interests co-operating with the colliery people in this country at an early date, to set about putting down coke ovens, and then coming to the gas industry and asking it to take the surplus gas. Just a word of warning when that does arise. I think it would be wise to get into touch with some of those who have been using coke oven gas for some years and have arrived at a satisfactory arrangement for purchasing and for holding down the coke oven people to supply a gas of a steady calorific value from hour to hour. In that way you will be able to get contracts fixed which will not let you down as I have known gas engineers to be let down when they did not have such contracts. The result was that they lost a large number of gas consumers for ever. I say this is a position which will probably arise; and I do not think, generally speaking, that the problem of coke ovens for gas-works of medium or even fairly large size, apart from those away from the coalfields, is likely to confront the gas engineer of this generation.

Mr. W. M. CARR (Stretford): Mr. Gill has mentioned the question of mixing coke oven gas with coal gas. We have been doing this at Stretford to a limited extent, and hope very shortly to carry it out on a larger scale; but the difficulty we have experienced is arranging for the proper mixing of the dilution gas. I do think it is a great advantage that, when working with a mixture of coke oven and coal gas plant, it is possible to keep the whole of the plant working, and divert the gas from the surplus plant which is not needed for coal gas requirements to the purpose of heating the settings. Of course, we believe we can do that equally well and equally satisfactorily with our vertical or horizontal plant if we apply it to our settings. In this same connection there is the question of the life of the settings. There is no doubt about it that coke ovens have worked satisfactorily in America, giving a ten years' life; and I believe that when we can fire our retorts, whether they are vertical or horizontal, with clean gas—be it clean producer gas or clean coal gas—we will then get a life equal to that of coke ovens. To do this, however, they must be kept continuously working. I think this is a very important point; and there is no reason why our settings should not last as long as coke oven settings if we fire them with clean gas. In mentioning the question of guarantee as to life of settings, Mr. Gill said it was a *sine quâ non* that the setting should be fired with clean gas; and I should like to ask Mr. Gill whether he has found that the oven settings that are fired by the self-contained producer are showing the same life as the oven settings fired with clean gas.

Mr. GILL, replying to the discussion, said: I would first like to refer to Mr. Thomas Glover's remarks. He said—and I agree with him—that the future is likely to point to continuous verticals with carbonization in larger charges. It may be in retorts or ovens of different systems, but that we shall have to go to continuous verticals or bulk carbonization. He said those were the tendencies. Personally, I have the very highest opinion of continuous vertical retorts, and in my paper my whole idea is simply to bring forward systems which are apt to be left in the background because the gas engineer does not think of the oven at all when he is going to reconstruct his works. I do think you can make out a strong case for considering carbonization in bulk. The President spoke about the mechanical producer, and I also have noticed at times the same thing that he has noticed. You often hear that these mechanical producers burn fine breeze as well as small coke, but when you inquire, you find they are only burning small coke. In the United States, however, you encounter a different experience. I know many plants there where they use up all their coke breeze. I have been to the Rochester Works in the States three times; and their retorts are heated entirely with producer gas, and they use up all their breeze. I have been up to the hoppers, and have taken particular notice of what they are doing. In a number of other works, also, there is no doubt that the mechanical producers use about 40 p.ct. of breeze; but it has got to be large enough for its duty. If you are going to use fine material, then the producer must be a little larger than if you are using coke. It is a question of capacity. Then as regards the fuel consumption in these mechanical producers, I think I shall be right in saying that the fuel consumption would be about 1100 B.Th.U. per pound of coal carbonized. This only gives you a general idea.

Mr. Chamberlain seemed to have got the idea that these continuous systems would not have flexibility. I think it is just the opposite. I think you would have much more flexibility than is the case with ordinary systems, because, for instance, in the winter you may want to make a little more or a little less coal gas, according to conditions. There may be a cold snap or a mild spell; and with this oven system you simply use a little more coal gas or no coal gas. You use the mechanical producer more or less, and vary the duration of the charge. There are several ways of getting flexibility; and in the States the fluctuations of the load are, I suggest, much greater than at Sheffield. In the States you constantly have temperatures below zero in the winter, and the temperature flies right up in the summer, when there are great variations. The summer is much hotter than in this country, and the winter is much colder; and the difference in their loads is much greater than in this country. Therefore, from that point of view, you would expect them to adopt a system which would suit these varying conditions. I have come across places in the States where the winter load is three times the summer load. I have been asked whether, as a consequence of varying the charge, the gas also varies. No, so long as you keep the system reasonably gas tight, you can make what gas you like. My experience of horizontal retorts is that you can vary the duration from 10 hours to 20 hours without any difficulty in this respect. I have never had any trouble myself in doing this; and it is as easy with ovens.

Mr. Hardie spoke about the use of breeze in the mechanical producer, but most people consider it an advantage to be able to dispose of their breeze in this way. I rather gathered from what Mr. Hardie said that he would prefer to use his breeze in his boilers. A number of people with mechanical producers do this. They employ their breeze in boilers and their small coke in mechanical producers. It seems to me a matter of local conditions. I was pleased to hear Mr. McLusky's remarks, as he has seen a great deal of what I have observed in the States. Mr. Townsend asked whether I could produce a chart of the gas from ovens. I have not got one, but I have seen many, and they certainly satisfied me in regard to the uniformity of the gas that can be made. He also spoke of the use of the term "waste-heat boiler" in connection with a producer plant. He is right. You cannot call it a waste-heat boiler, although it is of that type; that is what I really meant. There is much sensible heat in the producer gas, and in those cases the desire is to clean the gas so that they can use it in metal cocks, and obtain the control they desire. It is a fact that you can put in a boiler to convert that sensible heat into steam, which steam is used for providing the power for working the producer gas plant. In this way they recover the heat. I am much indebted to Mr. Ruthven for his explanations, which have made the system of intermittent vertical ovens clear. Mr. Harris corrected me for saying that the first installation was at Ramsgate; and I thank him for his correction.

The amount of space taken up by these horizontal ovens is

certainly greater than that occupied by continuous verticals, and if one had a congested space to work in, such as the centre of London, nobody in his senses would dream of putting in these large horizontal ovens. I notice that in the discussion nobody has referred to the smaller horizontal ovens. The discussion has seemed to turn on the question whether ovens would be suitable for gas-works operations. This was not really the point of the paper. It was to describe the various sizes and systems of ovens. I think Mr. Jackson based his remarks on the ovens you see about in England; but my paper had nothing whatever to do with these old types of coke oven. Their gas might not be suitable, and I made it a point that in the new coke ovens with narrow ovens and silica walls you have an entirely different system, and one capable of making the same gas in every way that you manufacture in your retorts. I do not think this would apply to 90 p.ct. of the ovens in this country; and special precautions would have to be taken with old types of ovens to give you the gas you want.

Mr. Carr spoke of firing with coal gas. It is simply a question of cost, and whether you can sell your coke. You have to balance one thing against another. He also spoke of the effect of clean gas on the life of the retort; and I agree entirely. If you heat your retorts or ovens with clean gas, you will get a longer life; and if you use the plant summer and winter continuously, you are going to get a much longer life still. I am afraid I cannot answer Mr. Carr's point about the sort of life they get with these small ovens with self-contained producers. I am afraid I have never paid any attention to it. I think this more or less answers all the questions that have been put; and as I know the President is very anxious to get on, I will conclude by thanking you for your attention to my paper, and for the way it has been received.

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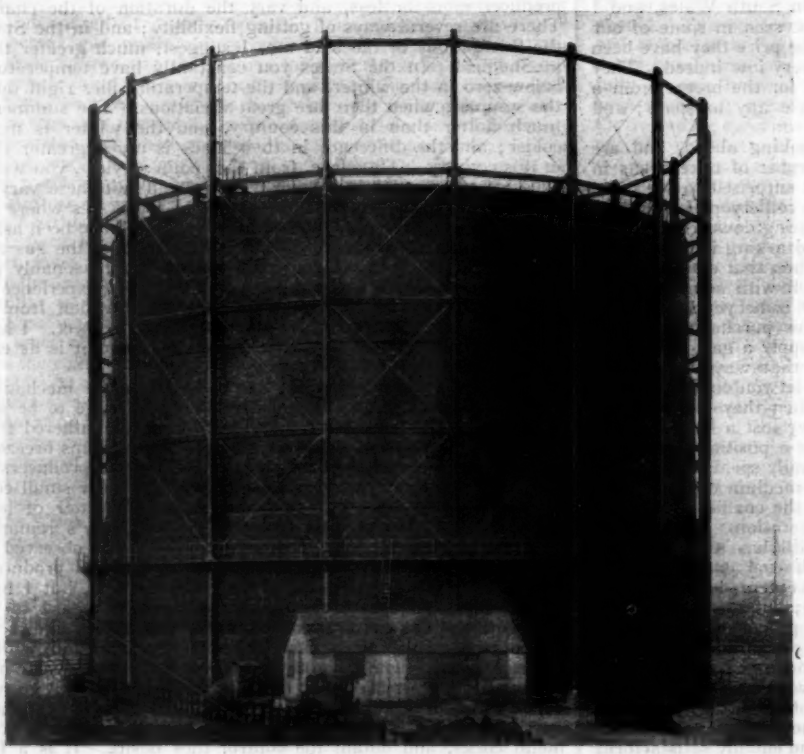

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GAS FELLOWSHIP 1927 REPORT.

INFLUENCE OF THE ASH CONSTITUENTS IN THE CARBONIZATION AND GASIFICATION OF COAL.

Part III.—GASIFICATION OF SPECIAL COKES.

(*a*) **In Steam—By J. A. SUTCLIFFE, B.A. (Oxon.), (Gas Research Fellow), and J. W. COBB, C.B.E., B.Sc., F.I.C. (Livesey Professor).** (*b*) **In Carbon Dioxide—By W. R. BRANSON, B.Sc., and J. W. COBB.**
(*c*) **In Oxygen—By F. J. DENT, B.Sc., and J. W. COBB.**

PRELIMINARY NOTE.

The work described below is divided into three parts, which are submitted together because they all deal with the gasification of special cokes made by the addition of inorganic constituents, such as sodium carbonate, oxide of iron, and lime, to coal. The first part deals with gasification in steam, and has been carried out by Mr. J. A. Sutcliffe, Gas Research Fellow. It is a continuation of the investigation reported upon last year. The second part, dealing with gasification in carbon dioxide, was carried out by Mr. W. R. Branson, who received a grant from the Fuel Research Board for the purpose. The third part sets out results obtained in the study of the behaviour of these special cokes in air or oxygen, and was carried out by Mr. F. J. Dent.

J. W. C.

GENERAL INTRODUCTION AND SUMMARY.

As set out in the Gas Research Fellowship Report for 1926, the influence of the ash constituents in the carbonization and gasification of coal had been further examined by gasifying in steam special cokes which had been made by the addition of 5 p.ct. of various oxides to a coal containing originally only 1 p.ct. of ash, followed by carbonization. Some of these additions had proved of no effect; but sodium carbonate, ferric oxide, and lime had exercised a remarkable influence on the rate of gasification and the quality of the water gas made. The phenomenon was plainly worthy of further investigation. The experiments had been made at 1000° C. and one obvious point of interest was how far the differences of reactivity in the cokes were maintained at different temperatures of gasification. A set of experiments was made with this in view. The results at lower temperatures were equally striking, a very noticeable feature being the low carbon dioxide content of the gas made at 800° C. with sodium carbonate coke.

It was also important to know what results would be obtained if the quantity of the addition was cut down, and whether some special influence might be exerted by two of the constituents added together. It was shown that the smaller quantities had a much more than proportionate effect, which is important from the economic standpoint if additions are to be made on the large scale. On the other hand, no special advantage seemed to be realized by adding a mixture instead of a single constituent.

In considering what is likely and possible in practice, we had to remember the abnormally low ash content (1 p.ct.) of the coal to which additions had been made; and further trials were made with a coal more normal as to the quantity of ash it contained (4·5 p.ct.). Moreover, the composition of the ash is obviously likely to be of importance; and this second ash was of a much more basic character. As was expected, the influence of an added constituent was smaller in this case, though still quite marked.

Another matter of considerable interest was how far the influence of the ash constituent was in evidence when the carbonization was made on a large scale. As regards the appearance of the coke, experiments made on the Corbet-Woodall experimental gas plant (see Eighteenth Report, Gas Investigation Committee), using 30-lb. charges, would suggest that the influence of the ash constituent was small. This is not very remarkable when one considers the nature of coke formation as dependent on the rate of gas evolution through a fused mass. The influence on the reactivity of the coke, however, remained.

REACTIVITY IN CARBON DIOXIDE.

Although we were at first concerned with the stimulating effect of ash constituents on the reactivity of coke in steam, the results obtained seemed to be such as justified experiments on other gases. Reactivity to carbon dioxide is probably the most important of all. The formation of carbon monoxide from carbon dioxide is at the root of the manufacture of producer gas by blowing air through a deep column of coal or coke, is all-important to the working of the blast furnace, and plays its part in every coal or coke fire.

We have extended our observations in the first place to the behaviour with carbon dioxide. A similar apparatus was used (with suitable modifications) to secure comparable results as between steam and carbon dioxide, and the experiments were made through a considerable temperature range. The same (or even greater) enhancement of reactivity was noted as with steam.

Lower temperatures were used in the laboratory comparison than with steam, because of the higher reactivities. 1 p.ct. of oxide of iron was found to give more than half the enhanced effect which came from 5 p.ct. An impregnated sodium carbonate coke was proved to be almost as active as one prepared by adding the sodium carbonate before carbonization.

With some of the special cokes, and more particularly the sodium carbonate coke, there was a falling off in reactivity to carbon dioxide as an experiment proceeded. An interesting observation was made in this connection. The shape of the curves for the 5 p.ct. oxide of iron coke would suggest that reduced iron may be present, which is oxidized by the carbon dioxide, giving rise for a little time to increased quantities of carbon monoxide. It was found that if the coke was treated with hydrogen after the period of highest reactivity had passed, and a steady state had been attained, the state of higher reactivity was regenerated. Passing hydrogen over the pure coke or sodium carbonate coke, on the other hand, appeared to be of no effect. It was determined, too, that little or no falling away occurred with sodium carbonate coke with steam, although it was so pronounced with carbon dioxide.

REACTIVITY WITH AIR.

It is difficult to test for differences between cokes as to their reactivity with air at temperatures above the ignition point. This is largely owing to the experiment getting out of hand on account of rise in temperature when air or oxygen is used. We have made some attempts by limiting their heating effect in two ways; by using air diluted with nitrogen until it contained only 2 to 3 p.ct. of oxygen, and by leading it over a small flat surface of coke ground to fit into a fireclay boat, so exposing a limited surface. Measurement showed that by this method it was possible to obtain combustion without any accumulation of heat or rise in temperature. Working at 800° C., no differences could be determined in the cokes examined. The variations obtained are within the limits of experimental error when working at the higher speeds employed in order to get very small times of contact.

Another set of experiments was made, raising the temperature by stages from 300° to 800° C. The curves indicate that above 700° C. the behaviour of all the cokes is practically the same, but that at lower temperatures—

400° to 600° C.—they show wide differences. The opinion has been previously put forward that at high temperatures the reactivity of cokes in general is so high in air that differences in behaviour come to depend upon the rate of supply of air to the coke particles rather than on the reactivity of the cokes. Our results would confirm this opinion.

One remarkable feature of the curves obtained in these experiments was the slowness with which the highly reactive sodium carbonate coke began to react with oxygen. The same phenomenon had been noticed in some experiments made on the temperature of ignition of the special cokes, and is being further investigated.

It was proved by direct experiment that when air is supplied to a bed of coke the temperature generated in the bed is higher when the coke is less reactive, presumably because less of the carbon dioxide generated is reduced to carbon monoxide in a reaction which absorbs heat.

Part III.—GASIFICATION OF SPECIAL COKES.

(*a*) In Steam. By J. A. SUTCLIFFE, B.A. (Oxon.) (Gas Research Fellow), and J. W. COBB (Livesey Professor).

EXPERIMENTAL WORK.

PREPARATION OF COKES.

The addition of inorganic compounds was made to portions of a Sharlston Wallsend coal containing originally 1·2 p.ct. of ash. The coal mixtures were carbonized in small fireclay retorts by the method described in the Gas Research Fellowship Report of 1925. A quantity of the untreated coal was also carbonized in the same way. All cokes were prepared at a temperature of 800 ° C.; the total carbonizing period being six hours.

DESCRIPTION OF APPARATUS AND METHOD OF WORKING.

In order to correlate our results with those given in the Gas Research Fellowship Report of 1926, we have adopted substantially the same experimental method. The apparatus is almost identical, and the results obtained are given in a similar form. A diagram showing part of the apparatus is given in fig. 1.

Purified nitrogen, saturated with steam at a known and accurately controlled temperature, was passed over a column of coke (7 cm. long, 2·2 cm. diameter) enclosed in a Morgan reaction tube and packed into position with silica blocks. Prior to each experiment, air was removed by evacuation and subsequent replacement by nitrogen. During the process of heating the reaction tube to the desired temperature, the apparatus was swept with dry nitrogen in order to carry away any traces of moisture which might be present.

All the cokes under examination were crushed, and material passing through a sieve of $\frac{1}{8}$ in. aperture, but retained on a sieve of $\frac{1}{4}$ in. aperture, was employed (after drying at 105° C.).

All experiments were carried out at a temperature of 1000° C. *unless otherwise stated, with a steaming rate of approximately* 10 *litres per hour, using* 10 *grammes of coke.*

The gasification products were collected and estimated as follows:

(*a*) Undecomposed steam gravimetrically by absorption with calcium chloride.

(*b*) Carbon dioxide gravimetrically by soda lime. Hydrogen sulphide in the gas stream was first removed by absorption with pumice impregnated with copper sulphate.

(*c*) Carbon monoxide, hydrogen, and methane volumetrically by analyses made with the modified Bone and Wheeler apparatus.

After each experiment the apparatus was swept with dry nitrogen.

METHOD OF REPORTING RESULTS.

All gas volumes are corrected to N.T.P. and calculated as hourly rates. The rate of steam supply was estimated by weighing the saturator before and after each experiment. As a check, the value ($H_2 + H_2O$) is also recorded in the tables—*i.e.*, the volume of hydrogen produced *plus* the volume of undecomposed steam. If all the hydrogen were obtained solely from the decomposition of the steam, this value ($H_2 + H_2O$) should be identical with the amount of steam supplied as measured by the loss in weight of the saturator. Furthermore, if the only reactions occurring were:

$$(1)\ C + H_2O \rightarrow CO + H_2$$
$$(2)\ C + 2H_2O \rightarrow CO_2 + 2H_2$$

it is plain that the volume of hydrogen produced would be equal to ($CO + 2CO_2$). The value ($CO + CO_2$) indicates the rate of gasification of the carbon.

The volume of dry water gas recorded does not include that of the methane, which is small in amount and is given in the dry gas compositions. The time of contact was calculated from the mean of the volumes of gas entering (steam and nitrogen) and gas leaving (water gas, water vapour, and nitrogen).

GASIFICATION OF COKES CONTAINING MIXTURES OF INORGANIC COMPOUNDS.

The Gas Research Fellowship Report of 1926 contained results which showed that additions of such compounds as ferric oxide, calcium carbonate, and sodium carbonate to coal prior to carbonization influenced the percentage of steam decomposed by the coke obtained in a remarkable manner, and, furthermore, a water gas was obtained of a lower carbon dioxide content. It was considered desirable to investigate the effect of mixtures of these compounds. Smaller quantities than before were added in these and many subsequent experiments, partly with a view to possible practical applications. For this purpose the following additions were made:

(1) A mixture of $\frac{1}{2}$ p.ct. ferric oxide and $\frac{1}{2}$ p.ct. sodium oxide (added as sodium carbonate).

(2) A mixture of $\frac{1}{2}$ p.ct. ferric oxide and $\frac{1}{2}$ p.ct. calcium oxide (added as calcium carbonate).

(3) A mixture of $\frac{1}{2}$ p.ct. calcium oxide and $\frac{1}{2}$ p.ct. sodium oxide (added as their respective carbonates).

The cokes obtained differed little in appearance from that of the "pure" coke (which will be referred to as "pure" coke I.).

The results of gasifying these cokes in steam are given in Tables 1 and 1 (continued) and, for the purpose of comparison, the results of gasifying cokes containing $\frac{1}{2}$ p.ct. and 1 p.ct. of a single inorganic constituent are also quoted. The figures show that the cokes containing mixtures of $\frac{1}{2}$ p.ct. of each of two inorganic compounds are more reactive than the cokes containing $\frac{1}{2}$ p.ct. of one compound only; the amount of steam decomposed rising, for example, from 75·2 p.ct. in the case of the coke containing $\frac{1}{2}$ p.ct. of iron oxide to 82·6 p.ct. in the case

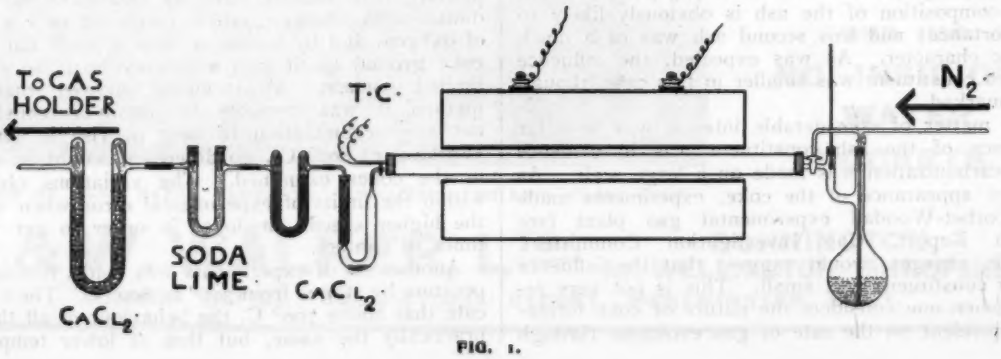

FIG. 1.

of the coke containing a mixture of ½ p.ct. iron oxide with ½ p.ct. sodium oxide. The cokes containing 1 p.ct. of iron oxide or 1 p.ct. of sodium oxide are, however, more reactive than the cokes containing ½ p.ct. of each of the two compounds; the percentages of steam decomposed being 86·3 and 88·4 respectively. In the case of the cokes containing a mixture of ½ p.ct. calcium oxide with either ½ p.ct. iron oxide or ½ p.ct. sodium oxide, the amounts of steam decomposed (83·5 p.ct. and 81·3 p.ct. respectively) are intermediate between the amounts of steam decomposed by the coke containing 1 p.ct. calcium oxide (74·8 p.ct.) and the cokes containing 1 p.ct. ferric oxide or 1 p.ct. sodium oxide. No special virtue appeared thus to be attached to the addition of oxide mixtures as compared with single oxides.

Gasification of Cokes Containing Salts of the Alkali Metals.

Quantities of potassium carbonate, sodium sulphate, and sodium chloride equivalent to ½ p.ct. of their respective oxides were added to the coal, which was then carbonized. The cokes obtained differed little in appearance from that of the "pure" coke I.

The results of gasifying these cokes are given in Tables 2 and 2 (continued) and, for the purpose of comparison, the results of gasifying the "pure" coke I. and the coke containing ½ p.ct. sodium oxide (added as sodium carbonate) are also quoted.

The potassium carbonate and sodium sulphate cokes were similar to the sodium carbonate coke as regards the percentage of steam decomposed and the carbon dioxide content of the water gas produced. The coke containing sodium chloride, however, was distinctly less reactive towards steam than the sodium carbonate coke, though more reactive than the "pure" coke. The amounts of steam decomposed by the "pure" coke, sodium chloride coke, and sodium carbonate coke respectively were 62·7, 71·6, and 77·6 p.ct. A small quantity of soda as carbonate or sulphate is therefore an effective addition. Sodium chloride is less active, possibly because of its greater volatility.

The Effect of Additions of Mineral Constituents to a Coal of a Higher and more Normal Ash Content.

The additions referred to above had been made, as stated, to a Sharlston Wallsend coal containing originally 1·2 p.ct. of ash. It was considered advisable to determine how far the effect of such additions would be modified if they were made to a coal of a higher natural ash content. The coal used was a Nottinghamshire coal, containing 4·5 p.ct. of ash.

Table No. 1.—*Special Cokes at 1000° C. in Steam.*

Nature of Addition.	Series No.	Experiment No.	Rate of Steam Supply. Litres per Hour at N.T.P.	Duration of Steaming in Minutes.	Steam Decomposed. P.Ct.	Coke Gasified. P.Ct.	Coke Gasified. Grammes per Hour.	Vol. Dry Water Gas Produced. Litres per Hour at N.T.P.	Vol. Dry Water Gas Vol. Steam Supplied.	Average Time of Contact. Seconds.
½ p.ct. Fe_2O_3	I.	2	10·35	35	75·2	24·3	4·1	15·05	1·45	0·76
½ p.ct. Na_2O as Na_2CO_3		3	10·79	35	77·6	28·0	4·8	15·79	1·46	0·74
½ p.ct. Fe_2O_3 + ½ p.ct. Na_2O as Na_2CO_3		4	10·54	35	82·6	28·0	4·8	16·54	1·57	0·74
½ p.ct. CaO as $CaCO_3$ + ½ p.ct. Na_2O as Na_2CO_3		5	10·51	35	81·3	27·4	4·7	16·28	1·55	0·75
½ p.ct. Fe_2O_3 + ½ p.ct. CaO as $CaCO_3$		6	10·50	35	83·5	29·3	5·0	17·05	1·62	0·74
1 p.ct. Fe_2O_3		44 (1926 Report)	9·1	45	86·3	36·8	4·9	16·45	1·8	0·79
1 p.ct. Na_2O as Na_2CO_3		7	11·24	30	88·4	29·5	5·9	19·14	1·7	0·72
1 p.ct. CaO as $CaCO_3$		36	10·16	35	74·8	24·4	4·2	13·90	1·36	0·80

Table No. 1 (*continued*).

Experiment No.	Litres per Hour at N.T.P. of Wet Gas Constituents. CO_2.	CO.	CO + CO_2.	H_2.	H_2O.	H_2 + H_2O.	CH_4.	N_2.	CO + $2CO_2$.	CO / (CO + CO_2).	(CO)(H₂O) / (CO_2)(H_2).	Dry Gas Compositions. Percentages by Volume. CO.	CO_2.	H_2.	CH_4.
2	0·84	6·16	7·00	8·04	2·57	10·61	0·12	5·3	7·84	0·880	2·33	40·7	5·6	53·0	0·7
3	1·10	6·21	7·31	8·48	2·42	10·90	0·11	5·3	8·41	0·849	1·61	39·0	6·9	53·3	0·8
4	0·83	7·16	7·99	8·56	1·83	10·39	0·11	5·3	8·82	0·896	1·84	43·0	5·0	51·4	0·6
5	0·90	6·75	7·65	8·63	1·97	10·60	0·12	5·2	8·55	0·882	1·71	41·2	5·5	52·6	0·7
6	0·74	7·32	8·06	8·99	1·74	10·73	0·04	5·2	8·80	0·909	1·92	42·9	4·3	52·6	0·2
44	0·62	7·25	7·87	8·58	1·24	9·8	0·09	5·1	8·49	0·922	1·69	43·8	3·7	51·9	0·6
7	0·69	8·45	9·14	9·99	1·30	11·29	0·15	4·7	9·83	0·924	1·59	43·8	3·6	51·8	0·8
36	1·16	5·26	6·42	7·49	2·56	10·05	0·14	5·1	7·58	0·819	1·55	37·4	8·3	53·4	0·9

Table No. 2.—*"Alkali" Cokes at 1000° C. in Steam.*

Nature of Addition.	Series No.	Experiment No.	Rate of Steam Supply. Litres per Hour at N.T.P.	Duration of Steaming in Minutes.	Steam Decomposed. P.Ct.	Coke Gasified. P.Ct.	Coke Gasified. Grammes. per Hour.	Vol. Dry Water Gas Produced Litres per Hour at N.T.P.	Vol. Dry Water Gas Vol. Steam Supplied.	Average Time of Contact. Seconds.
"Pure" coke I.	II.	1	10·23	45	62·7	24·2	3·2	11·64	1·14	0·82
½ p.ct. Na_2O as Na_2CO_3		3	10·79	35	77·6	28·0	4·8	15·79	1·46	0·74
½ p.ct. K_2O as K_2CO_3		8	10·98	35	77·8	26·9	4·6	16·22	1·48	0·74
½ p.ct. Na_2O as Na_2SO_4		9	10·95	35	78·0	27·4	4·7	16·16	1·48	0·74
½ p.ct. Na_2O as NaCl		10	10·50	35	71·6	24·0	4·1	13·96	1·33	0·77

Table No. 2 (*continued*).

Experiment No.	Litres per Hour at N.T.P. of Wet Gas Constituents. CO_2.	CO.	CO + CO_2.	H_2.	H_2O.	H_2 + H_2O.	CH_4.	N_2.	CO + $2CO_2$.	CO / (CO + CO_2).	(CO)(H₂O) / (CO_2)(H_2).	Dry Gas Compositions. Percentages by Volume. CO.	CO_2.	H_2.	CH_4.
1	1·20	4·12	5·32	6·32	3·82	10·14	0·10	5·1	6·52	0·775	2·09	35·1	10·2	53·8	0·9
3	1·10	6·21	7·31	8·48	2·42	10·90	0·11	5·3	8·41	0·849	1·61	39·0	6·9	53·3	0·8
8	1·11	6·47	7·58	8·64	2·44	11·08	0·09	5·0	8·69	0·854	1·65	39·7	6·8	53·0	0·5
9	1·03	6·50	7·53	8·63	2·40	11·03	0·12	5·1	8·56	0·863	1·75	39·9	6·3	53·0	0·8
10	1·17	5·13	6·30	7·66	2·98	10·64	0·11	5·3	7·47	0·814	1·71	36·5	8·3	54·5	0·7

One p.ct. and three p.ct. of each of the following substances were added to separate portions of this coal, prior to carbonization:

(*a*) Sodium oxide (added as sodium carbonate).
(*b*) Calcium oxide (added as calcium carbonate).
(*c*) Iron oxide.

A sample of the "pure" coal was also carbonized.

Appearance of the Cokes.

All the cokes were homogeneous and close grained in structure, including the "pure" coke (which will be referred to as "pure" coke II.), which thus differed considerably from the swollen "pure" coke I. obtained from the Sharlston Wallsend coal. The addition of 1 p.ct. and 3 p.ct. of iron oxide caused the coke produced to be very soft and friable. It crumbled into powder so readily that it was difficult to grade. The addition of 1 p.ct. and 3 p.ct. of sodium oxide (added as sodium carbonate) gave a coke somewhat harder and darker in colour than the "pure" coke II. There was little difference in appearance between the calcium carbonate cokes and the "pure" coke II.

The results of gasifying these cokes in steam are given in Tables 3 and 3 (continued). The tables show that all the additions are effective in enhancing the reactivity of the cokes towards steam; sodium carbonate is more effective than iron oxide, and the latter is more effective than calcium carbonate. It is interesting to note that the "pure" coke II. is very much more reactive than the Sharlston Wallsend "pure" coke. Thus, for the same rate of steam supply, the percentages of steam decomposed were 63 for the Sharlston Wallsend "pure" coke, and 90 for the coke of higher natural ash content, while the corresponding percentages of CO_2 in the water gas were 10·2 and 2·8 respectively. These differences may be accounted for by the differences in the ash of the two types of coal or in the coal substance. An attempt was made to remove the ash from the Nottinghamshire coal by adding the coal to water containing small quantities of paraffin and cresylic acid, which was agitated until a froth was obtained containing the cleaned coal.

In this way the ash was reduced to 1·86 p.ct.—*i.e.*, less than a half. The reactivity of the coke obtained on carbonization was, however, practically the same as that of the coke obtained from the untreated coal.

The addition of 1 p.ct. sodium oxide as sodium carbonate to the coal in which the ash had been substantially lessened gave on carbonization a coke of properties identical with those of the coke obtained by the same addition to the untreated coal.

It is interesting to compare the Sharlston Wallsend and Nottinghamshire coals as regards their organic constituents and also the quantity and character of the natural ash which they contained. The analyses of the two coals are given below. The Nottinghamshire coal contained more oxygen, and was of a distinctly less fusible and caking character. The ash of that coal was much more basic in character (containing much more iron oxide) and greater in quantity, which would partially account for the greater reactivity of the coke made from it.

Sharlston Wallsend Coal.	
Proximate Analysis.	P.Ct.
Loss at 105° C.	2·3
Volatile matter	35·8
Fixed carbon	60·7
Ash	1·2
	100·0
Ultimate Analysis.	P.Ct.
Loss at 105° C.	2·3
Carbon	81·3
Hydrogen	5·3
Nitrogen	1·9
Total sulphur	1·0
Ash	1·2
Oxygen (by difference)	7·0
	100·0
Analysis of Ash (Oxidized).	P.Ct.
Silica (SiO_2)	41·4
Iron oxide (Fe_2O_3)	11·3
Aluminium oxide (Al_2O_3)	29·0
Calcium oxide (CaO)	5·5
Magnesium oxide (MgO)	1·8
Sulphuric anhydride (SO_3)	4·4
Not estimated	6·6
	100·0

Nottinghamshire Coal.	
Proximate Analysis.	P.Ct.
Volatile matter	36·8
Fixed carbon	58·7
Ash	4·5
	100·0
Ultimate Analysis.	P.Ct.
Carbon	78·4
Hydrogen	4·8
Nitrogen	1·7
Total sulphur	1·4
Ash	4·5
Oxygen (by difference)	9·2
	100·0
Analysis of Ash.	P.Ct.
Silica (SiO_2)	29·1
Iron oxide (Fe_2O_3)	20·8
Aluminium oxide (Al_2O_3)	15·6
Calcium oxide (CaO)	13·0
Magnesium oxide (MgO)	trace
Sulphuric anhydride (SO_3)	15·7
Not estimated	5·8
	100·0

Gasification of Special Cokes Carbonized on a Larger Scale.

The Research Staff of the Gas Investigation Committee have carbonized on a much larger scale (33 lbs. per charge) the Nottinghamshire coal to which the following additions were made:

(1) 2 p.ct. iron oxide.
(2) 2 p.ct. sodium oxide (added as sodium carbonate).
(3) 2 p.ct. calcium oxide (added as calcium carbonate).

The cokes thus obtained showed an increase in their re-

Table No. 3.—*Special Cokes from Nottinghamshire Coal at 1000° C. in Steam.*

Nature of Addition.	Series No.	Experiment No.	Rate of Steam Supply. Litres per Hour at N.T.P.	Duration of Steaming in Minutes.	Steam Decomposed. P.Ct.	Coke Gasified. P.Ct.	Coke Gasified. Grammes per Hour.	Vol. Dry Water Gas Produced. Litres per Hour at N.T.P.	Vol. Dry Water Gas / Vol. Steam Supplied.	Average Time of Contact. Seconds.
"Pure" coke II.	III.	11	10·03	35	90·2	30·5	5·2	17·50	1·74	0·77
1 p.ct. Fe_2O_3		12	9·93	35	94·1	33·8	5·8	18·46	1·86	0·77
1 p.ct. Na_2O as Na_2CO_3		13	9·82	30	95·8	29·3	5·9	18·51	1·89	0·74
1 p.ct. CaO as $CaCO_3$		14	10·64	30	90·9	29·3	5·9	18·91	1·78	0·72
3 p.ct. Fe_2O_3		15	10·40	35	97·2	35·5	6·1	19·94	1·92	0·73
3 p.ct. Na_2O as Na_2CO_3		16	9·64	30	99·7	31·6	6·3	18·86	1·96	0·74
3 p.ct. CaO as $CaCO_3$		17	9·54	35	94·5	32·4	5·6	17·95	1·88	0·79
"Pure" coke (after removal of ash)		18	10·35	35	89·2	31·3	5·4	18·13	1·75	0·73
1 p.ct. Na_2O as Na_2CO_3 to original coal (after removal of ash)		19	10·59	30	95·6	32·0	6·4	20·26	1·91	0·69

Table No. 3 (*continued*).

Experiment No.	Litres per Hour at N.T.P. of Wet Gas Constituents. CO_2.	CO.	CO + CO_2.	H_2.	H_2O.	H_2 + H_2O.	CH_4.	N_2.	CO + 2CO_2.	CO / CO+CO_2	(CO) (H$_2$O) / (CO$_2$) (H$_2$).	Dry Gas Compositions. Percentages by Volume. CO.	CO_2.	H_2.	CH_4.
11	0·49	7·87	8·36	9·14	0·98	10·12	0·07	4·7	8·85	0·941	1·71	44·8	2·8	52·0	0·4
12	0·29	8·65	8·94	9·52	0·59	10·11	0·08	4·5	9·23	0·967	1·81	46·6	1·6	51·3	0·5
13	0·22	8·80	9·02	9·49	0·41	9·90	0·11	5·3	9·24	0·975	1·72	47·2	1·2	51·0	0·6
14	0·42	8·68	9·10	9·80	0·97	10·77	0·11	5·0	9·52	0·954	2·04	45·6	2·2	51·6	0·6
15	0·19	9·71	9·90	10·05	0·29	10·34	0·11	4·9	10·09	0·981	1·50	48·4	0·9	50·1	0·6
16	0·04	9·38	9·42	9·45	0·03	9·48	0·03	5·5	9·46	0·996	0·76	49·6	0·2	50·0	0·2
17	0·18	8·67	8·85	9·11	0·53	9·64	0·11	4·6	9·03	0·980	2·83	48·0	1·0	50·5	0·5
18	0·58	8·17	8·75	9·38	1·12	10·50	0·07	5·3	9·33	0·934	1·68	44·9	3·2	51·5	0·4
19	0·17	9·68	9·85	10·41	0·47	10·88	0·12	5·6	10·02	0·983	2·59	47·5	0·8	51·1	0·6

activity towards steam (compared with the "pure" coke, which is referred to as "pure" coke III.) similar to the increase in reactivity observed when the carbonization was performed in the laboratory.

The results of gasifying these cokes in steam are shown in Tables 4 and 4 (continued) and other interesting results obtained on carbonization are given in the Eighteenth Report of the Gas Investigation Committee.

Gasification of Special Cokes at Different Temperatures.

The "pure" coke I., obtained from the Sharlston Wallsend coal, and the cokes obtained by additions of 5 p.ct. of iron oxide and sodium oxide (added as sodium carbonate) to this coal were gasified in steam at temperatures of 600° C., 700° C., 800° C., 900° C., and 1000° C. The results are shown in Tables 5 and 5 (continued) and fig. 2.

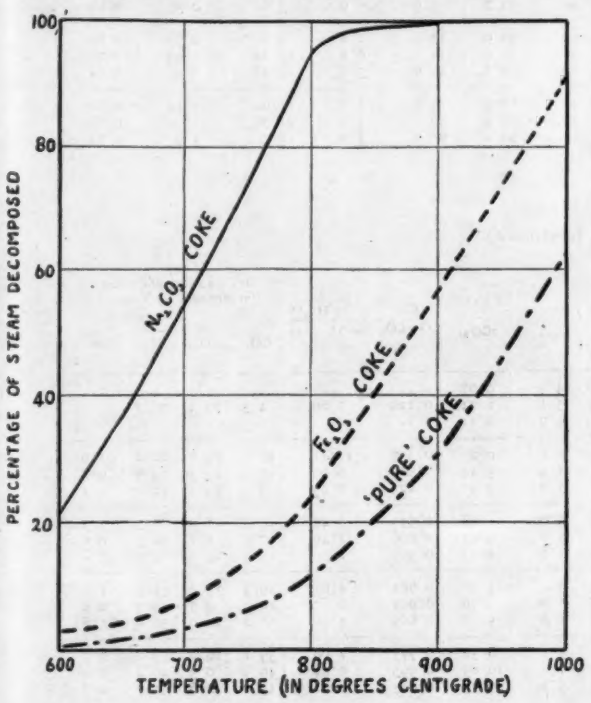

FIG. 2.

At the five temperatures quoted the percentages of steam decomposed by the "pure" coke I. are 0·7, 3·5, 11·6, 30·9, and 62·7 respectively, while the percentages of carbon dioxide in the water gas produced at the temperatures from 700° C. upwards are 24·7, 18·0, 13·8, and 10·2. The values for the ratio $\frac{(CO)\,(H_2O)}{(CO_2)\,(H_2)}$ are very high at the lower temperatures, showing that the reaction products were far from having attained equilibrium. Too much reliance, however, cannot be placed on the values at low temperatures in the case of the "pure" coke and iron oxide coke, nor on the values at high temperatures in the case of the sodium carbonate coke, owing to the small quantities of gases or water vapour available for estimation.

The behaviour of the sodium carbonate coke was very different. Even at 600° C. and 700° C. the percentages of steam decomposed were 21·5 and 53·9 respectively. The percentages of carbon dioxide in the water gas were high—29·4 and 19·3 respectively. At 800° C., however, the percentage of steam decomposed was 95, while the percentage of carbon dioxide in the water gas had fallen to 1·7. At 900° and 1000° C. the steam decomposition was practically complete, and the water gas produced contained only 0·5 and 0·3 p.ct. respectively of carbon dioxide.

The iron oxide coke was also more reactive than the pure coke at all the temperatures examined, but to a lesser degree than the sodium carbonate coke. The percentages of steam decomposed at 600° C., 700° C., 800° C., 900° C., and 1000° C. were 3·0, 7·8, 24·5, 56·8, and 91·4. The values for the ratio $\frac{(CO)\,(H_2O)}{(CO_2)\,(H_2)}$ were much lower than for pure coke, indicating that a closer approximation to equilibrium was attained in the gaseous products. The result of this, however, is the production of an inferior water gas at 800° C. and 900° C., where the percentage of steam undecomposed is comparatively high in both cases.

For the purpose of reference the values obtained by Hahn for the ratio $\frac{(CO)\,(H_2O)}{(CO_2)\,(H_2)}$, if equilibrium is attained, are quoted below:

Temperature, °C.	$K\left(=\frac{(CO)\,(H_2O)}{(CO_2)\,(H_2)}\right)$
686	0·53
786	0·84
886	1·20
986	1·57
1205	2·13
1405	2·49

Reactivity of the Sodium Carbonate Coke.

Experiments performed by Mr. W. R. Branson (described below) indicated that the reactivity of the sodium carbonate coke, when it was gasified in a current of carbon dioxide, decreased in a marked manner as gasification proceeded. Experiments have therefore been performed to investigate whether the same phenomenon would be manifested when this coke was gasified in steam. The method adopted was similar to that employed by Mr. Branson (described below): the products of gasification issuing from the reaction tube, instead of passing to the adsorption train and gasholder as shown in fig. 1, were sampled from time to time. The samples were analyzed on the modified Bone and Wheeler apparatus. The undecomposed steam was not estimated, since it was con-

TABLE No. 4.—*Special Cokes Carbonized on Larger Scale at 1000° C. in Steam.*

Nature of Addition.	Series No.	Experiment No.	Rate of Steam Supply. Litres per Hour at N.T.P.	Duration of Steaming in Minutes.	Steam Decomposed. P.Ct.	Coke Gasified. P.Ct.	Coke Gasified. Grammes per Hour.	Vol. Dry Water Gas Produced. Litres per Hour at N.T.P.	Vol. Dry Water Gas / Vol. Steam Supplied.	Average Time of Contact. Seconds.
"Pure" coke III.	IV.	20	10·18	30	85·0	25·1	5·0	16·54	1·63	0·75
2 p.ct. Na_2O as Na_2CO_3		21	11·02	30	97·7	36·2	7·2	21·58	1·96	0·69
2 p.ct. Fe_2O_3		22	10·74	30	94·6	33·7	6·8	20·07	1·87	0·71
2 p.ct. CaO as $CaCO_3$		23	9·82	30	92·1	29·3	5·9	17·66	1·80	0·76

TABLE No. 4 (*continued*).

Experiment No.	Litres per Hour at N.T.P. of Wet Gas Constituents.								$\frac{CO}{CO+2CO_2}$	$\frac{CO}{CO+CO_2}$	$\frac{(CO)\,(H_2O)}{(CO_2)\,(H_2)}$	Dry Gas Compositions. Percentages by Volume.			
	CO_2.	CO.	$\frac{CO}{CO+CO_2}$	H_2.	H_2O.	$\frac{H_2}{H_2+H_2O}$	CH_4.	N_2.				CO.	CO_2.	H_2.	CH_4.
20	0·78	7·14	7·92	8·61	1·53	10·14	0·08	5·4	8·70	0·902	1·63	43·0	4·7	51·8	0·5
21	0·13	10·60	10·73	10·85	0·26	11·11	0·09	4·8	10·86	0·988	1·96	48·9	0·6	50·1	0·4
22	0·28	9·61	9·89	10·19	0·58	10·77	0·07	5·0	10·17	0·972	1·97	47·7	1·4	50·6	0·3
23	0·44	8·19	8·63	9·04	0·77	9·81	0·07	5·0	9·07	0·949	1·61	46·2	2·5	51·0	0·3

TABLE No. 5.—*Gasification of Special Cokes at Different Temperatures in Steam.*

Temp.	Description of Coke.	Series No.	Experiment No.	Rate of Steam Supply. Litres per Hour at N.T.P.	Duration of Steaming in Minutes.	Steam Decomposed. P.Ct.	Coke Gasified P.Ct.	Coke Gasified. Grammes per Hour.	Vol. Dry Water Gas Produced. Litres per Hour at N.T.P.	Vol. Dry Water Gas. / Vol. Steam Supplied.	Average Time of Contact. Seconds.
600° C.	"Pure" coke I.	V.	24	10·83	40	0·7	..	..	..	..	..
	5 p.ct. Na_2O as Na_2CO_3		25	9·59	40	21·5	7·6	1·1	2·75	0·29	0·97
	5 p.ct. Fe_2O_3		37	10·69	41	3·0	1·1	0·2	0·24	0·02	0·94
700° C.	"Pure" coke I.	VI.	26	10·78	45	3·5	3·6	0·5	0·44	0·04	0·92
	5 p.ct. Na_2O as Na_2CO_3		27	11·09	45	53·9	23·3	3·1	9·41	0·85	0·83
	5 p.ct. Fe_2O_3		28	9·63	40	7·8	0·9	0·1	0·93	0·10	1·00
800° C.	"Pure" coke I.	VII.	29	10·42	50	11·6	7·9	0·9	2·03	0·19	0·93
	5 p.ct. Na_2O as Na_2CO_3		30	9·52	35	95·0	33·9	5·8	17·89	1·88	0·77
	5 p.ct. Fe_2O_3		31	9·83	40	24·5	5·9	0·9	3·63	0·37	0·97
900° C.	"Pure" coke I.	VIII.	32	10·36	50	30·9	13·6	1·6	5·67	0·55	0·89
	5 p.ct. Na_2O as Na_2CO_3		33	9·67	30	99·6	34·0	6·8	19·22	1·99	0·75
	5 p.ct. Fe_2O_3		34	10·44	40	56·8	20·6	3·1	10·28	0·99	0·84
1000° C.	"Pure" coke I.	IX.	1	10·23	45	62·7	24·2	3·2	11·64	1·14	0·82
	5 p.ct. Na_2O as Na_2CO_3		35	10·75	30	99·9	39·7	7·9	21·39	1·99	0·70
	5 p.ct. Fe_2O_3		20 (1926 Report)	9·6	45	91·4	38·9	5·2	18·1	1·9	0·74

TABLE No. 5 (*continued*).

Experiment No.	Litres per Hour at N.T.P. of Wet Gas Constituents.								$\frac{CO}{2CO_2}$	$\frac{CO}{CO+CO_2}$	$\frac{(CO)\ (H_2O)}{(CO_2)\ (H_2)}$	Dry Gas Compositions. Percentages by Volume.			
	CO_2.	CO.	CO + CO_2.	H_2.	H_2O.	H_2 + H_2O.	CH_4.	N_2.				CO.	CO_2.	H_2.	CH_4.
24	0·035	..	0·035	0·06	10·76	10·82	..	4·4	0·07	..	..	..	..	..	..
25	0·81	0·12	0·93	1·82	7·53	9·35	..	5·1	1·74	0·126	0·60	4·3	29·4	66·3	..
37	0·055	..	0·055	0·18	10·38	10·56	0·03	4·9	0·11	..	..	..	..	..	..
26	0·11	0·05	0·16	0·28	10·40	10·68	0·01	5·1	0·27	0·317	17·41	11·5	24·7	62·2	1·6
27	1·83	1·83	3·66	5·75	5·11	10·86	0·08	4·9	5·49	0·500	0·89	19·3	19·3	60·6	0·8
28	0·22	0·03	0·25	0·68	8·88	9·56	0·02	5·0	0·47	0·123	1·83	3·3	23·4	71·2	2·1
29	0·37	0·42	0·79	1·24	9·22	10·46	0·02	5·0	1·16	0·533	8·49	20·5	18·0	60·3	1·2
30	0·30	8·53	8·83	9·06	0·47	9·53	0·11	5·0	9·13	0·966	1·49	47·4	1·7	50·3	0·6
31	0·89	0·39	1·28	2·35	7·43	9·78	0·09	4·8	2·17	0·306	1·39	10·5	24·0	63·1	2·4
32	0·79	1·69	2·48	3·19	7·16	10·35	0·07	4·8	3·27	0·682	4·810	29·5	13·8	55·5	1·2
33	0·09	9·60	9·69	9·54	0·04	9·58	0·12	5·0	9·78	0·991	0·47	49·6	0·5	49·3	0·6
34	1·46	2·96	4·42	5·86	4·51	10·37	0·19	4·9	5·88	0·669	1·56	28·2	14·0	56·0	1·8
1	1·20	4·12	5·32	6·32	3·82	10·14	0·10	5·1	6·52	0·775	2·09	35·1	10·2	53·8	0·9
35	0·06	10·73	10·79	10·60	0·01	10·61	0·09	4·9	10·85	0·995	0·24	49·9	0·3	49·4	0·4
20	0·47	8·19	8·66	9·40	0·80	10·2	0·12	5·4	9·13	0·945	1·52	45·0	2·6	51·7	0·7

sidered that any marked decrease in the reactivity of the coke would be made apparent by a rise in the carbon dioxide content of the products of gasification, and, further, by a fall in the ratio $\frac{\text{Vol. water gas}}{\text{Vol. nitrogen}}$, since the rate of passage of nitrogen and steam were maintained constant throughout the experiments.

The experiments performed up to the present have been made under the following conditions of temperature and rate of steam supply:

(*a*) Temperature 1000° C.; rate of steam supply 10 litres per hour.
(*b*) Temperature 850° C.; rate of steam supply 4 litres per hour.
(*c*) Temperature 750° C.; rate of steam supply 3·5 litres per hour.

The experiments indicated that the reactivity of the sodium carbonate coke towards steam did not decrease to any marked extent as gasification proceeded (until such a quantity of coke was gasified that the experimental conditions were altered), but further work is necessary in order to decide the question finally.

WORK OF OTHERS.

The gaseous mixture formed when steam reacts with coke is considered to be formed by some or all of the following reactions:

(1) $C + H_2O = CO + H_2$
(2) $C + 2H_2O = CO_2 + 2H_2$
(3) $CO + H_2O = CO_2 + H$
(4) $C + CO_2 = 2CO$

The presence of inorganic compounds in the ash may influence some or all of these reactions.

The Gas Research Fellowship Report of 1924 described experiments carried out on the gasification of low, medium, and high temperature cokes at the two temperatures of 900° C. and 1000° C. At 900° C. a good water gas, low in carbon dioxide, was not obtained with any of the steaming rates tried. At 1000° C. a good water gas was obtained with rates of steam supply below 2 litres per hour. As the rate of steam supply was increased the percentage decomposed diminished and the carbon dioxide content of the water gas increased. The products of gasification were in equilibrium according to the water gas reaction until a rate of steam supply of about 10 litres per hour was reached, and it was pointed out that the high iron content of the coke ash might be responsible for this.

The Gas Research Fellowship Report of 1926 described experiments carried out on the gasification of cokes prepared from coal to which 5 p.ct. of such oxides as silica, alumina, lime, and ferric oxide, and of equivalent quantities of calcium carbonate and sodium carbonate, had been added. Whereas silica, alumina, or fireclay influenced the percentage of steam decomposed to no appreciable extent, lime, ferric oxide, and sodium carbonate influenced the results in a remarkable manner, giving a much higher steam decomposition with a lower carbon dioxide content in the gas for the same rate of steam supply. The results also indicated that the increased reactivity of the special cokes was largely due to the specific catalytic effect of the added compound, rather than to the alteration in physical structure on carbonization resulting from the addition.

Gwosdz (Z. Angew. Chem. 1918, *31*, pp. 137-140) considered that even at low temperatures (600° C.) carbon dioxide was not formed by reaction (2), but that the carbon dioxide comes from reaction (3) speeded up catalytically by ash in the carbon. He arrived at this conclusion from the fact that with arc-lamp carbon containing 0·1 p.ct. ash the $CO : CO_2$ ratio was about 11 : 1, whereas with charcoal containing 1·4 p.ct. ash the $CO : CO_2$ ratio was about 1 : 5.

Haslam, Hitchcock, and Rudow (J. Ind. and Eng.

Chem. *15*, 1923, pp. 115-121) examined the effect of steaming coke and arc carbon at various temperatures

(*a*) under a pressure of half an atmosphere, and
(*b*) under a pressure of one and a half atmospheres.
(See Gas Research Fellowship Report, 1924.)

They concluded that both carbon monoxide and carbon dioxide must both be initially formed products of the interaction of steam on carbon and, further, that though temperature does exert a small effect, the influence of undecomposed steam was the controlling factor in determining the amount of carbon dioxide formed or the CO : CO_2 ratio between the temperatures of 900° C. and 1200° C.

Taylor and Neville (J. Amer. Chem. Soc., 1921 *43*, 2065; for summary of paper see Gas Research Fellowship Report 1926) investigated the effects of catalysts on the reaction of carbon with steam at temperatures of 490°, 525°, and 570° C. They concluded that the acceleration of the reaction $C + CO_2 = 2CO$ was not due to alternate reduction and re-formation of the alkali carbonates, which might occur as follows:

$$K_2CO_3 + C = K_2O + 2CO$$
$$K_2O + CO_2 = K_2CO_3$$

but was caused by increased adsorption of carbon dioxide by the carbon surfaces in presence of active catalytic agents. Reduced nickel as a catalyst, however, exhibited anomalous behaviour. Its activity in the carbon dioxide-carbon reaction was greater than that of the other catalysts, but its effect on the adsorptive capacity of carbon was less and, further, its effect on the steam carbon reaction diminished with increasing time of gasification. As an explanation it was suggested that the nickel became coated with a deposit of carbon, due to acceleration of the reverse reaction:

$$2CO = C + CO_2.$$

Part III.—GASIFICATION OF SPECIAL COKES.

(*b*) In Carbon Dioxide. By W. R. BRANSON, B.Sc., and J. W. COBB, C.B.E., B.Sc., F.I.C.

EXPERIMENTAL.

The essential portions of the apparatus are shown diagrammatically in fig. 3. Ten grammes of coke were placed in a horizontal tube of non-porous material (Morgan fireclay) 2·2 cm. in internal diameter and 55 cm. long. The coke occupied a length of 7 cm. in the centre of the tube; the remainder of the length being occupied with "Morgan" blocks drilled to take the thermocouple sheath and gas exit tube.

The thermocouple sheath was placed so that the junction of the couple was at the midpoint of the coke column. The Morgan tube was heated in an electric furnace, which was wound so as to give a practically uniform temperature over 8 in. of the length of the tube.

Carbon dioxide, derived from a cylinder, was freed from oxygen by passage over heated Cu gauze, no difficulty being experienced in keeping the oxygen below 0·1 p.ct. The carbon dioxide then passed through a water saturator, and was measured in an experimental wet meter; the saturator being introduced in order to minimize the waterlining of the meter. The carbon dioxide was then dried by concentrated sulphuric acid and calcium chloride, and passed through a capillary flow gauge, which was used to keep the rate of flow constant throughout an experiment.

A three-way tap was provided at the inlet to the reaction tube, to allow of the gas being passed to the atmosphere or to the reaction tube.

The meter and flow gauge were previously calibrated.

SAMPLING DEVICE.

At the outlet end of the reaction tube a second three-way tap was provided so that the tube could be connected either to the sampling arrangement or to a vacuum pump.

The gases escaped to the atmosphere through a water seal, a T-piece being provided through which samples were drawn into a mercury sampling bulb and transferred to a test tube over mercury for analysis in the Bone and Wheeler gas analysis apparatus. Thus, so long as gas was escaping at the seal, the pressure in the apparatus was constant and the rate of flow entirely undisturbed by sampling.

The cokes containing 5 p.ct. of added oxide, prepared as described in the Gas Research Fellowship Report 1925, were first gasified at 850° C., and a rate of carbon dioxide supply of approximately 6 litres per hour, as experiment showed that these conditions showed up the differences in the cokes to a suitable extent.

GASIFICATION OF SPECIAL COKES AT 850° C. AND 6 LITRES PER HOUR.

The results of these experiments are shown in Table 6, and some of them are illustrated graphically in fig. 4, where the percentage of carbon dioxide in the products has been plotted against time.

It will be seen that the addition of sodium carbonate has produced a great increase in reactivity, but that this activity falls very rapidly with time.

The iron oxide coke is initially more active than the lime or calcium carbonate cokes but gradually falls to a value intermediate between the lime (and calcium carbonate) coke and the "pure" coke. The curve for calcium carbonate coke has not been plotted in fig. 4, as it is almost coincident with the lime coke curve. In this connection it is interesting to note that Marson and Cobb* found the iron oxide coke more reactive in steam than the lime coke.

* Gas Research Fellowship Report, 1926.

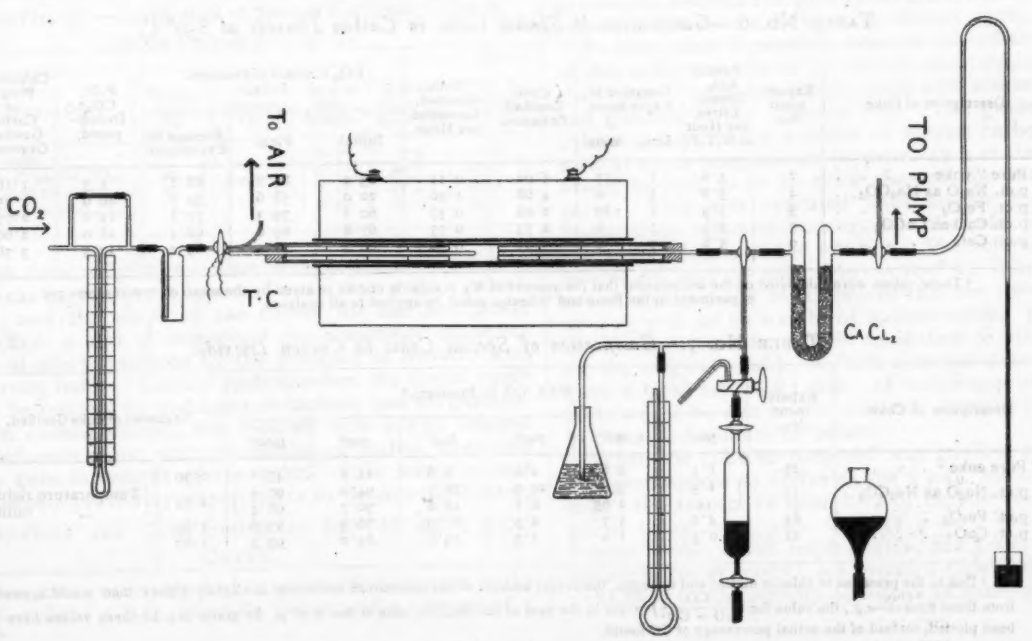

FIG. 3.

The coke residues in all cases appeared to occupy approximately the same volume as prior to gasification. The residue from Experiment 4 (5 p.ct. sodium oxide as sodium carbonate) was very black and had lost the silvery lustre, while those from Experiments 7 and 9 (lime and calcium carbonate) exhibited a whitish grey appearance not noticeable prior to gasification.

EFFECT OF TEMPERATURE ON THE ACTIVITY OF THE SPECIAL COKES.

In these experiments the rate of carbon dioxide supply was kept the same as in the previous series (*i.e.*, 6 litres per hour), and a quick determination of reactivity was made at temperature intervals of 100° C. between 500° and 1000° C. The furnace was first heated to 500° C., and the carbon dioxide stream turned on; after 15 mins. a sample was taken for analysis, and 5 mins. later the carbon dioxide was turned off and heating continued up to 600° C.

A second determination was made at 600° C. lasting a similar period, and so on at 100° intervals up to 1000° C. The results of the experiments are shown graphically in fig. 5 and Table 7.

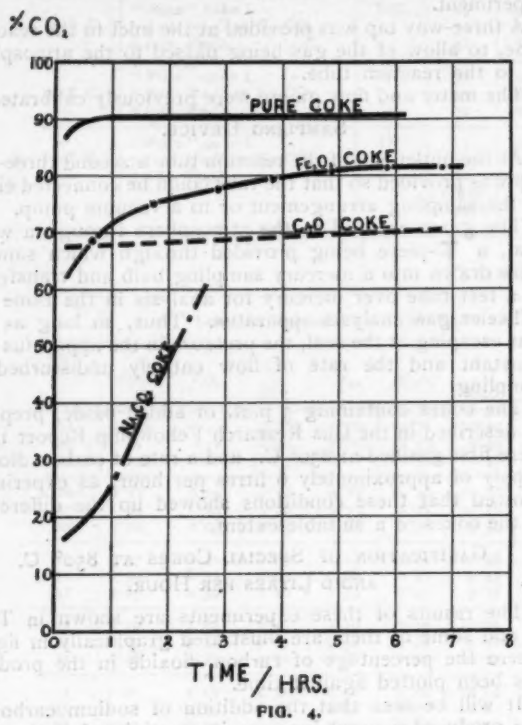

FIG. 4.

To ascertain how far the fall in activity with time would influence the shape of the curves obtained for the sodium carbonate coke (Experiment 12), this coke was examined for a second period of 20 minutes at each temperature by allowing the furnace to cool 100° C. between each determination (see Table 7).

The coke residue from Experiment 10 (calcium oxide coke) showed the whitish grey surface previously noted in the case of Experiment 7 with calcium carbonate coke. Considerable difficulty was experienced in these experiments with calcium oxide coke at temperatures rather above 850° C. due to the deposition in the gas outlet tube of an objectionable-smelling white solid having a waxy appearance.

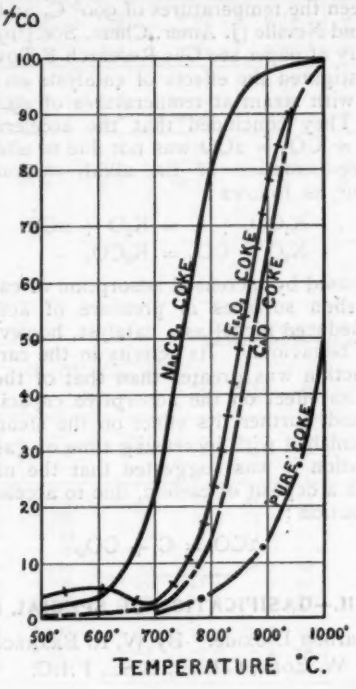

FIG. 5.

The shape of the curve for the iron oxide coke at low temperatures is interesting, and will be discussed later.

The differences between the cokes at 1000° C. will be seen to be slight compared with those found at 850° C. This does not necessarily mean that the differences do not exist, but merely that they are not detected under the conditions employed.

TABLE No. 6.—*Gasification of Special Cokes in Carbon Dioxide at 850° C.*

Description of Coke.	Experiment No.	Rate of CO_2 Supply. Litres per Hour at N.T.P.	Duration of Experiment. Hrs.	Mins.	Coke Gasified. Grammes.	Coke Gasified. Grammes per Hour.	CO_2 Content of Products. P.Ct. Initial.	Final.	Average for Experiment	P.Ct. CO_2* Decomposed.	Calculated Weight of Carbon Gasified. Grammes.
"Pure" coke	2	5·6	7	17	1·02	0·14	83·2	87·8	88·8	5·3	1·16
5 p.ct. Na_2O as Na_2CO_3	4	5·8	3	0	4·68	1·56	22·0	58·6	34·8	46·9	4·45
5 p.ct. Fe_2O_3	5	5·9	7	10	2·66	0·37	62·1	79·3	77·1	12·1	2·77
5 p.ct. CaO as $CaCO_3$	7	5·5	5	0	2·73	0·55	67·6	69·2	68·4	18·0	2·66
5 p.ct. CaO	9	5·6	7	0	3·91	0·56	66·2	71·1	69·2	17·5	3·76

* These values were calculated on the assumption that the amount of N_2 + volatile matter as given by the mean of two analyses per experiment in the Bone and Wheeler could be applied to all analyses.

TABLE No. 7.—*Gasification of Special Cokes in Carbon Dioxide.*

Description of Coke.	Experiment No.	P.Ct. CO in Products.* 500°	600°	700°	800°	900°	1000°	Grammes of Coke Gasified.	
"Pure coke	15	1·1	0·6	1·0	4·6	14·0	47·8	0·70	
5 p.ct. Na_2O as Na_2CO_3	12	1·9	3·6	20·9	76·5	94·0	97·4	4·73	Temperature rising.
		..	2·65	6·1	16·8	70·7	96·4		falling.
5 p.ct. Fe_2O_3	13	4·2	5·7	2·5	21·0	70·3	93·0	1·89	
5 p.ct. CaO	11	0·5	1·0	1·3	13·6	63·2	95·3	1·67	

* Due to the presence of volatile matter and nitrogen, the actual amount of decomposition occurring is slightly higher than would appear from these figures—*e.g.*, the value for $\left(\frac{CO}{CO + CO_2}\right) \times 100$ in the case of the Na_2CO_3 coke at 800 is 76·3. In graph (fig. 4.) these values have been plotted, instead of the actual percentage of CO found.

GASIFICATION OF SPECIAL COKES AT 700° C.

To obtain measurable amounts of decomposition at 700° C., the rate of carbon dioxide supply was dropped to 0·4 litre per hour. This entailed slight modifications in the experimental apparatus. The results of these experiments are shown in Table 8. The chief points of interest in this series are the sodium carbonate and iron oxide cokes.

The sodium carbonate coke, which showed such a rapid fall in activity at 850° C., shows a constant value throughout. Since, however, even in an experiment which lasted 25 hours, the loss in weight was only 1·6 grammes, while in Experiment 4 at 850° C. 4·7 grammes were gasified in about three hours, it may be that insufficient gasification had taken place for the change in activity to occur. It remains to carry out an experiment sufficiently long at 700° C. to confirm this.

The loss in weight of the iron oxide coke (Experiment 18) is less than the calculated loss by a small amount; and the same applies to the 850° C. series (Experiment 5).

p.ct. The gasifications were carried out in the same way as the 5 p.ct. cokes, and the results are shown in Table 9, from which it will be seen that the effect of 1 p.ct. additions is, generally, to increase the amount of decomposition occurring by an amount slightly greater than half that produced by 5 p.ct. additions. The 1 p.ct. calcium oxide (as calcium carbonate) gave a very slightly higher decomposition than the 5 p.ct. calcium oxide (as calcium carbonate).

GASIFICATION OF 1 P.CT COKES AT 700° C.

The gasification of these cokes at 700° was carried out in exactly the same way as the 5 p.ct. cokes; and the results are shown in Table 10. In this case the results are again intermediate between the "pure" and the 5 p.ct. cokes; and there is no anomaly in the case of the lime coke as at 850° C.

IMPREGNATED SODIUM AND POTASSIUM CARBONATE COKES.

The structure of the sodium carbonate coke prepared as

TABLE No. 8.—*Gasification of Special Cokes in Carbon Dioxide at 700° C.*

Description of Coke.	Experiment No.	Rate of CO_2 Supply. Litres per Hour at N.T.P.	Duration of Experiment. Hrs.	Mins.	Coke Gasified. Grammes.	Coke Gasified. Grammes per Hour.	$\frac{CO \times 100}{CO + CO_2}$ Initial.	Final.	Average for Experiment	P.Ct. CO_2 Decomposed.	Calculated Weight of Carbon Gasified. Grammes.
"Pure" coke	17	0·40	7	0	0·18	0·03	4·2	5·0	5·5	2·8	0·04
5 p.ct. Na_2O as Na_2CO_3	19	0·44	11	0	1 08	0·10	50·0	45·0	52·4	35·5	0·93
5 p.ct. Fe_2O_3	18	0·37	4	0	0·06	0·015	28·1	16·1	20·1	11·2	0·09
5 p.ct. CaO	22	0·44	6	0	..	..	18·8	8·7	13·5	7·2	0·11

TABLE No. 9.—*Gasification of Special Cokes in Carbon Dioxide at 850° C.*

Description of Coke.	Experiment No.	Rate of CO_2 Supply. Litres per Hour at N.T.P.	Duration of Experiment. Hrs.	Mins.	Coke Gasified. Grammes.	Coke Gasified. Grammes per Hour.	$\frac{CO \times 100}{CO + CO_2}$ Initial.	Final.	Average for Experiment	P.Ct. CO_2 Decomposed.	Calculated Weight of Carbon Gasified. Grammes.
"Pure" coke	37	5·8	4	0	0·572	0·14	12·5	8·8	11·2	5·9	0·75
1 p.ct. Na_2O as Na_2CO_3	36	5·8	4	0	3·61	0·90	45·5	44·7	44·3	28·4	3·60
1 p.ct. Fe_2O_3	34	5·9	4	0	1·43	0·36	21·8	21·6	20·9	11·7	1·51
1 p.ct. CaO as $CaCO_3$	35	6·0	4	0	2·65	0·66	38·6	35·3	35·9	21·8	2·84

TABLE No. 10.—*Gasification of Special Cokes in Carbon Dioxide at 700° C.*

Description of Coke.	Experiment No.	Rate of CO_2 Supply. Litres per Hour at N.T.P.	Duration of Experiment. Hrs.	Mins.	Coke Gasified. Grammes.	Coke Gasified. Grammes per Hour.	$\frac{CO \times 100}{CO + CO_2}$ Initial.	Final.	Average for Experiment	P.Ct. CO_2 Decomposed.	Calculated Weight of Carbon Gasified. Grammes.
"Pure" coke	17	0·40	7	0	0·18	0·03	4·2	5·0	5·5	2·8	0·04
1 p.ct. Na_2O as Na_2CO_3	26	0·45	3	45	0·34	0·09	38·3	26·3	29·9	17·6	0·16
1 p.ct. Fe_2O_3	28	0 40	4	15	0 09	0·02	14·4	15·3	15·1	8·2	0·08
1 p.ct. CaO as $CaCO_3$	30	0·43	4	35	0·02	0·005	..	13·2	11·2	5·9	0·06

TABLE No. 11.—*Gasification of Sodium Carbonate Cokes in Carbon Dioxide at 700° C.*

Description of Coke.	Experiment No.	Temperature °C.	Rate of CO_2 Supply.	Average $\frac{CO \times 100}{CO + CO_2}$	P.Ct. CO_2 Decomposed.
"Pure" coke	17	700° C.	0·40	5·5	2·8
1 p.ct. Na_2O as Na_2CO_3	27		0·42	30·1	17·7
Impregnated Na_2CO_3	24		0·40	45·4	29·3
5 p.ct. Na_2O as Na_2CO_3	19		0·44	52·4	35·5

Though these weighings cannot be regarded as accurate to any great degree, yet it appeared more than a more coincidence; and the shape of the curves for the iron oxide coke (figs. 4 and 5) suggested the possibility of direct chemical effect produced by the presence of metallic iron or ferrous oxide. During carbonization the ferric oxide might be reduced by hydrogen or carbon, and on gasification in carbon dioxide the reduced iron might become oxidized once more, with production of carbon monoxide and a gain in weight of the coke. This seems almost conclusively proved by experiments to be described later.

PREPARATION AND GASIFICATION AT 850° C. OF 1 P.CT. COKES.

These cokes were prepared in an identical manner to the 5 p.ct. cokes; 1 p.ct. of oxide being added instead of 5

previously described is greatly different from the "pure" coke (Gas Research Fellowship Report 1926).

To determine, if possible, how far the enhanced activity of this coke was due to its altered structure, a sample of the "pure" coke was impregnated with sodium carbonate and gasified in the ordinary way. The graded "pure" coke was boiled in a solution of sodium carbonate saturated at room temperature (approx. 10 p.ct.) and then allowed to cool so as to draw the solution into the coke pores. This was repeated until no air bubbles were liberated on vigorous stirring, and the coke had all sunk below the surface of the solution. The solution was then filtered off, and the coke dried at 105° C. Titration of the solution before and after showed that the coke had taken up 2·75 p.ct. of its weight of sodium oxide. (N.B.—This is 2·75 p.ct. on coke, and is equivalent to about 2·0 p.ct. on the original coal.) An ash determination as a check gave a total ash of 4·1 p.ct., of which approximately 1·3 p.ct. would be due to the coal ash, leaving 2·8 p.ct. due to the added sodium carbonate.

When the coke so prepared was gasified at 700° C. it appeared almost as active as the 5 p.ct. sodium carbonate coke; the respective quantities of carbon dioxide decomposed being 28·7 p.ct. and 33 p.ct. The results for "pure" coke, 1 p.ct. impregnated, and 5 p.ct. sodium carbonate cokes at 700° C. are grouped together in Table 11.

At 850° C. the activity appeared as great as that of the

TABLE No. 12.—*Gasification of "Alkali" Cokes in Carbon Dioxide at 850° C.*

Description of Coke.	Experiment No.	Rate of CO_2 Supply. Litres per Hour at N.T.P.	Duration of Experiment. Hrs.	Mins.	Coke Gasified. Grammes.	Coke Gasified. Grammes per Hour.	$\frac{CO \times 100}{CO + CO_2}$ Initial.	Final.	Average for Experiment	P.Ct. CO_2 Decomposed.	Calculated Weight of Carbon Gasified. Grammes.
"Pure" coke	37	5·8	4	0	0·57	0·14	12·5	8·8	11·2	5·9	0·75
1 p.ct. Na_2O as Na_2CO_3	36	5·8	4	0	3·61	0·90	45·5	44·7	44·3	28·4	3·60
Impregnated K_2CO_3	43	5·8	3	5	4·33	1·40	62·9	62·4	61·0	43·9	4·25
Impregnated Na_2CO_3	41	..	3	30	5·16	1·47	88·8	49·3	63·6	46·6	..
5 p.ct. Na_2O as Na_2CO_3	45	5·9	4	0	6·90*	1·72*	93·0	30·2	62·6	45·5	5·91

*Coke sample undried, hence the high loss in weight.

5 p.ct. sodium oxide coke prepared in the ordinary way, but it showed signs of coming to a constant activity after about 3 hours, whereas the ordinary sodium carbonate coke appears to continue falling for 4 hours, at which point about 60 p.ct. of the coke has been gasified. The results for "pure" coke, 1 p.ct. sodium oxide, impregnated potassium carbonate, impregnated sodium carbonate, and 5 p.ct. sodium oxide at 850° C. are shown together for comparison in Table 12.

Owing to the extreme deliquescence of potassium carbonate, it was impossible to mix it satisfactorily with the coal in the ordinary way, and so the "pure" coke was impregnated in the same way as with sodium carbonate, by boiling in a 10 p.ct. solution of potassium carbonate. The ash content of the impregnated coke was 6·1 p.ct. By this means the sodium and potassium carbonates can be compared. It will be seen that the potassium carbonate is less active at 850° C. than sodium carbonate, and that its activity does not fall off with time. The coke was blackened to a much less extent than in the case of the sodium carbonate.

The potassium carbonate coke has not yet been gasified at 700° C.

EXPERIMENTS TO DETERMINE WHETHER REDUCED IRON OXIDE PLAYS ANY PART IN THE ACTIVITY OF THE IRON OXIDE COKE.

Bahr* suggests that at temperatures above 850° C. iron and carbon dioxide react, with the formation of ferrous oxide and carbon monoxide. The ferrous oxide is in turn reduced to metallic iron by carbon, and once more oxidized by carbon dioxide.

In our experiments some or all of the ferric oxide added to the coal was reduced during carbonization by either the carbon or the hydrogen present (Gas Research Fellowship Report 1925).

On gasification in carbon dioxide, metallic iron might be oxidized once more, producing carbon monoxide; and if the reduction by carbon

$$FeO + C \rightarrow CO + Fe \qquad (1)$$

were slower than the oxidation

$$Fe + CO_2 \rightarrow FeO + CO \qquad (2)$$

then the amount of iron would fall until a balance was attained. (The shape of the iron oxide coke curve in fig. 4 would suggest this as possible.) The result would be a fall in the reactivity from a high initial to a lower constant value. If now, after this state had been reached, the ferrous oxide (FeO) could be once more reduced to metallic iron, the initial activity of the coke should be temporarily restored until equilibrium was attained once more.

The coke residue from a previous experiment (5 p.ct. ferric oxide gasified at 850° C.) was taken, and, after a short examination in the usual way at 850° C., to ensure that the activity had not materially altered with keeping, the tube was swept out with nitrogen for an hour (at approximately 10 litres per hour), and then hydrogen at 20 litres per hour passed over the coke. A quantity of water was observed to come off soon after commencing the passage of hydrogen. After freeing the reaction tube from hydrogen by sweeping out with nitrogen for an hour, the carbon dioxide was again turned on, and the reactivity determined in the ordinary way. It was found that its initial activity had been completely restored, and the carbon dioxide-time curve once more followed the line plotted in fig 4.

In order to determine whether treatment with hydrogen had any effect on the coke substance, the "pure" coke was treated in the same way. The treatment with hydrogen had no effect; the percentage of carbon monoxide in the products being 11·3 p.ct. before, and 10·6 p.ct. after, passage of hydrogen.

If the whole of the activity of the coke above the constant value finally attained be attributed to action of the iron according to equation (2) or

$$2Fe + 3CO_2 \rightarrow Fe_2O_3 + 3CO \qquad (3)$$

the total amount of iron required would be 2 to 3 grammes. Since only about 0·5 gramme iron is present in 10 grammes of coke, some other reaction (probably according to equation (1)) must be assumed to take place at the same time, and the final value for reactivity will then depend upon the speed of this reaction.

In order to determine whether the carbon alone would reduce the ferrous oxide, a sample of the iron oxide coke was examined until its activity had fallen to a constant figure, which took about 3 hours. The tube was swept free from carbon dioxide with nitrogen, and heating continued in a stream of nitrogen for a further period of 3 hours. The reactivity determination was then made in the usual way, and showed that the initial activity had been restored by this treatment.

As it had been suggested that a somewhat similar explanation might fit the case of the sodium carbonate coke, a sample was heated in a stream of carbon dioxide for 1½ hours, when its activity had fallen appreciably. A stream of hydrogen was then substituted for carbon dioxide; and after 1 hour in hydrogen the tube was swept out with nitrogen for ½ hour. The reactivity was apparently unaffected by this treatment, so that the cases are evidently not analogous.

THE WORK OF OTHERS.

Bahr[1] passed oxygen through a layer of coke of definite height heated in an electric furnace. The coke was graded 2 to 3 mm. in size, and the temperatures employed were from 850° to 950° C. He measured the reactivity of the coke by the ratio

$$\frac{100 \times \text{p.ct. CO}}{\text{p.ct. CO} + 2 \times \text{p.ct. CO}_2}$$

obtained by analysis of the gaseous products.

Since under the conditions employed all cokes would burn up the oxygen completely in a very short time, this ratio would be practically unaltered were carbon dioxide substituted for oxygen. Study of a later paper[2] where he gives figures obtained by both methods shows that they are the same within the limits of experimental error. He found that the addition of iron compounds had a very marked catalytic effect—cokes treated with ferric chloride or sulphate having double the activity of the untreated coke—and that, by adding iron oxide or metallic iron to the coal prior to carbonization, large increases in activity were obtained with any coking coal. He found the influence of porosity to be small compared with such effects as were produced by iron compounds.

Arend and Wagner[3] also noted the effect of additions of iron compounds on the reactivity. Their method consisted essentially of passing carbon dioxide through a single lump of coke, 10 cm. long and 3 cm. in diameter, ground to fit the reaction tube, and luted at the ends with clay to prevent by-passing of carbon dioxide between the coke lump and the walls of the tube. This will not necessarily give the same results as the use of a column of finely broken coke. They found that porosity had a considerable influence on reactivity, but that the increased activity of cokes prepared by adding iron oxide to the coal was not solely due to the increased porosity, since the reactivity could be reduced by extraction with hydrochloric acid.

* Stahl und Eisen 44, 1-9, 39-42, 1924.

The increased porosity they attribute to evolution of carbon monoxide at 700° C. during carbonization.

Hollings and Siderfin[4] found that impregnation of coke with sodium carbonate solution greatly increased its activity towards carbon dioxide, but that this rapidly decreased as gasification proceeded. In the discussion on that paper J. G. King gave some account of experiments carried out by the Fuel Research Board on the reactivities of cokes, with special reference to the falling away from a high initial value.

REFERENCES.

1 Bahr, Stahl und Eisen, **44**, pp. 1-9, and 39-42 (1924).
2 Bahr and Fallböhmer, Das Gas- und Wasserfach, **42**, p. 909, **43**, p. 929, and **44**, p. 943.
3 Arend and Wagner, Rev. Met. 1924, **21**, p. 285.
4 Hollings and Siderfin, J.S.C.I., **46**, p. 76T.

Part III.—GASIFICATION OF SPECIAL COKES.

(*c*) In Air and Oxygen. By F. J. DENT, B.Sc., and J. W. COBB, C.B.E., B.Sc., F.I.C.

EXPERIMENTS. SERIES I.

THE GASIFICATION OF THE SPECIAL COKES IN OXYGEN AT 800° C.

DESCRIPTION OF APPARATUS.

The apparatus is shown diagrammatically in fig. 6. A mixture of oxygen and nitrogen, containing about 2 p.ct. of oxygen, passed from the gasholder A, through calcium chloride tubes B, through the calibrated rotameter flow gauge C, over the coke surface contained in the furnace tube D, past the sampling device F, and escaped into the atmosphere via a water seal at G. This water seal prevented air from being drawn into the apparatus while sampling, and also, by its bubbling, would tend to prevent streamline flow over the coke surface.

The electric furnace E was so wound as to give a constant temperature zone 12 cm. long.

All gas samples were collected over mercury, and analyzed in a Haldane gas analysis apparatus.

The apparatus could be swept out with purified nitrogen, which was contained in the nitrogen cylinder H, and entered the main circuit at the three-way tap L.

ARRANGEMENT INSIDE THE FURNACE TUBE.

The ends of two fireclay boats were cut off so as to give two channels of the form and dimensions shown in fig. 7*a*. Into one of the channels two shaped pieces of fireclay (AA^1, fig. 7*b*) were luted, leaving a space B between them. A sample of the coke to be studied was ground (on emery cloth followed by glass paper) to fit into the space B, so that its surface was exactly flush with the surfaces of the two pieces of fireclay AA^1. This coke surface was always 1·2 cm. wide (*i.e.*, the internal width of the channel), but its length varied in different experiments, and is given in the tables of results. The coke sample was kept in position with a lute of fireclay.

The second channel fitted over the one containing the coke sample, and served as a conduit for the gases led over the coke surface. In different experiments the internal cross-section of this conduit was varied by partly filling it with fireclay; and its dimensions are stated in the tables of results.

After the coke sample had been fixed in position, the two boats were bound together with nichrome wire, slipped over the end of a silica tube D (fig. 8), outside diameter 1 cm., and then placed inside a Morgan fireclay tube E, (fig. 8) 50 cm. long and 2·2 cm. internal diameter. This Morgan tube was supported vertically inside a vertical electric furnace.

Into the upper end of the two channels was placed the junction of a platinum : platinum-rhodium couple F (fig. 8). The stream of oxygen-nitrogen mixture was passed up the inner silica tube D, over the coke surface C,S (fig. 8) and out at G. To prevent the oxygen-nitrogen mixture escaping round the joint at H, and also through the crack between the two boats, the space between the boats, silica tube D, and Morgan tube E was filled with ground fireclay J (fig. 8). Fireclay blocks K (fig. 8) were placed round the thermocouple sheath so that the free space in the tube E was reduced to a minimum. With the above

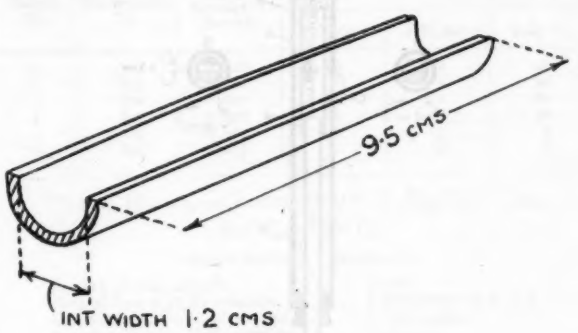

FIG. 7*a*.

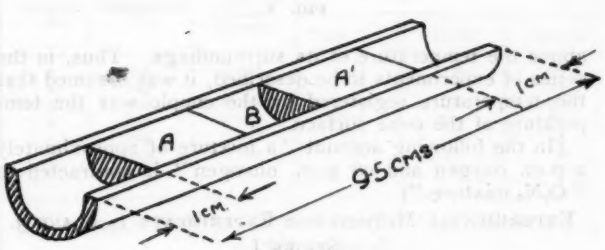

FIG. 7*b*.

arrangement it was found that with gas passing at 5 litres per hour the apparatus was swept out completely in 5 minutes.

The temperature registered by the couple F was assumed to be the temperature of the carbon surface. This

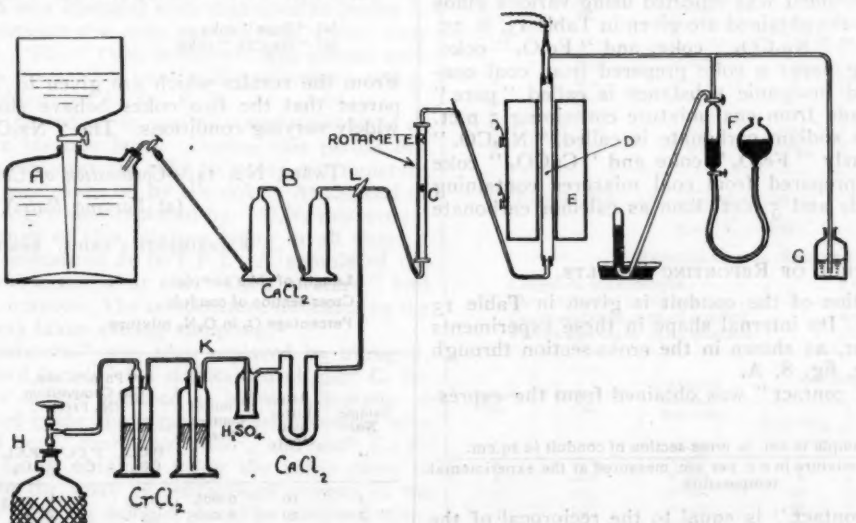

FIG. 6.

assumption was justified by a preliminary experiment in which the boat, containing a sample of coke, was placed in a glass tube, and heated in a Fletcher furnace to a bright redness; a stream of a mixture of oxygen and nitrogen being passed over it at 10 litres per hour. The coke surface was viewed through an optical pyrometer; and it was found that, if the oxygen content of the oxygen-nitrogen mixture was not greater than 3 p.c., the temperature of the coke surface did not rise more than 5°

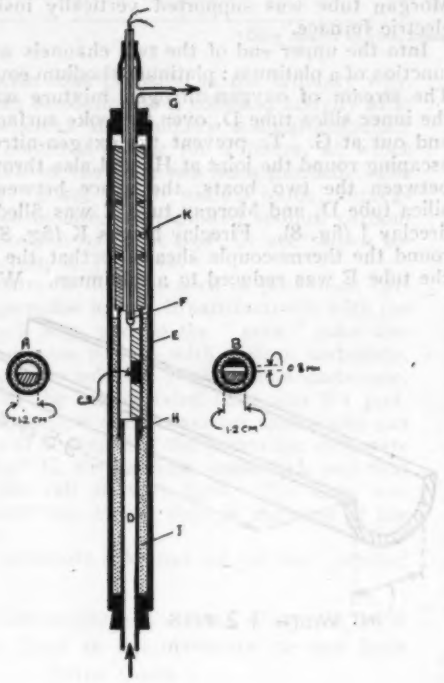

FIG. 8.

above the temperature of its surroundings. Thus, in the series of experiments to be described, it was assumed that the temperature registered by the couple was the temperature of the coke surface.

(In the following account "a mixture of approximately 2 p.ct. oxygen and 98 p.ct. nitrogen" is contracted to "O_2N_2 mixture.")

Experimental Method for Experiments 1, 2, and 3. Series I.

The furnace tube having been charged, the coke sample was heated up in a stream of purified nitrogen to 800° C., and maintained at that temperature for one hour. The nitrogen steam was then replaced by a stream of "O_2N_2 mixture" passing at 15·5 litres per hour. Samples of the outgoing gas were taken at various times, and analyzed. The experiment was repeated using various kinds of coke. The results obtained are given in Table 13, p. 55, for "pure coke," "Na_2CO_3" coke, and "Fe_2O_3" coke. (In the following paper a coke prepared from coal containing no added inorganic substance is called "pure" coke, a coke made from coal mixture containing 5 p.ct. sodium oxide as sodium carbonate is called "Na_2CO_3" coke, and similarly "Fe_2O_3" coke and "$CaCO_3$" coke apply to cokes prepared from coal mixtures containing 5 p.ct. iron oxide and 5 p.ct. lime as calcium carbonate respectively.)

Method of Reporting Results.

The cross-section of the conduit is given in Table 13 as 0·56 sq. cm. Its internal shape in these experiments was semi-circular, as shown in the cross-section through the furnace tube, fig. 8, A.

The "time of contact" was obtained from the expression:

$$\frac{\text{Length of coke sample in cm.} \times \text{cross-section of conduit in sq.cm.}}{\text{Rate of flow of } O_2N_2 \text{ mixture in c.c. per sec. measured at the experimental temperature.}}$$

The "time of contact" is equal to the reciprocal of the number of times the gas immediately over the coke surface is changed per second.

Table No. 13.—*Combustion of Cokes at 800° C.*

Length of coke sample . . . . 1 cm.
Rate of flow of O_2N_2 mixture . . 15·5 litres/hour at N.T.P.
Cross-sectional area of conduit . 0·56 sq. cm.
"Time of contact" . . . . . 0·032 sec.

Sample No.	Time. Mins.	P.Ct. O_2 in O_2N_2 Mixture.	Gas Composition. P.Ct. CO_2	P.Ct. CO	P.Ct. O_2
Experiment 1. Series I. "Pure" Coke.					
1	3–5	3·0	44	4	52
2	9–11	,,	50	5	45
3	19–21	,,	49	4	47
4	29–31	,,	46	3	51
5	39–41	,,	47	4	49
Experiment 2. Series I. "Na_2CO_3" Coke.					
1	3–5	2·4	48·5	7·5	44
2	9–11	,,	43	8	49
3	19–21	,,	41	8	51
4	29–31	,,	41	9	50
5	39–41	,,	41	8	51
Experiment 3. Series I. "Fe_2O_3" Coke.					
1	6–9	2·7	50	6	44
2	16–18	,,	50	5	45
3	26–28	,,	49	3	48
4	36–39	,,	45	6	49

Under the column headed "time," the two figures indicate the time in minutes over which the sample was taken; the time being measured from the commencement of the passing of O_2N_2 mixture. The "gas compositions" are calculated nitrogen free.

The results show that all the three cokes give very similar results. In the case of the "Na_2CO_3" coke the percentage of carbon monoxide appears a little higher and the carbon dioxide a little lower than in the case of the "pure" coke or "Fe_2O_3" coke; but all the variations are comparatively small.

In the next two experiments, Nos. 4 and 5, the conditions were modified, the cross-section of the conduit being reduced with fireclay packing, so that the gas had to flow over the coke through a slit 1·2 cm. wide and 0·8 mm. deep (see fig. 8, B). This was done so as to bring the gases into more thorough contact with the coke. The "time of contact" also was reduced by:

(*a*) Using a coke sample only 0·65 cm. long.
(*b*) Increasing the rate of passage of the O_2N_2 mixture.

The method of carrying out an experiment was as follows: The coke sample was heated in a stream of nitrogen to 800° C. and maintained at that temperature for one hour. The nitrogen was then replaced by a stream of "O_2N_2 mixture" passing at 10 litres per hour. After 5-6 minutes a sample of the outgoing gas was taken. The rate of gas flow was then increased to 20 litres per hour, and a further sample obtained. In this way, gas samples were obtained corresponding with rates of flow of O_2N_2 mixture of 10, 20, 35, and 50 litres per hour.

The experiment was carried out using:

(*a*) "Pure" coke . . . . . Experiment 4
(*b*) "Na_2CO_3" coke . . . . . ,, 5

From the results which are given in Table 14, it is apparent that the two cokes behave similarly even under widely varying conditions. The "Na_2CO_3" coke appears

Table No. 14.—*Combustion of Cokes at 800° C. (at Varying Rates).*

Experiments 4 and 5. Series I.

Length of coke sample . . . . . 0·65 cm.
Cross-section of conduit . . . . . 0·083 sq. cm.
Percentage O_2 in O_2N_2 mixture . . . . . 2·5 p.ct.

Sample No.	Rate. Litres per Hour.	Time of Contact. Secs.	"Pure" Coke. Gas Composition (N_2 Free). P.Ct. CO_2	P.Ct. CO	P.Ct. O_2	"Na_2CO_3" Coke. Gas Composition (N_2 Free). P.Ct. CO_2	P.Ct. CO	P.Ct. O_2
1	10	0·005	81·5	7	11·5	83	10	7
2	20	0·0025	55	8	37	50	8	42
3	35	0·0014	40	9	51	34	5	61
4	50	0·0010	29	5	66	21	5	74

to be slightly less reactive at the higher rates; and this may be due to:

(1) The greater ash content of the "Na_2CO_3" coke, which will tend to screen the surface; or
(2) the "pure" coke has a surface with much deeper "pits" in it than the "Na_2CO_3" coke. These "pits" leave exposed to the gases sharp edges and points at which reaction may be very liable to take place.

On the other hand, the difference between the cokes is comparatively small, and with the very small "times of contact" employed may be due to experimental error.

From the experiments of Series I. it may be concluded that the cokes examined showed the same rate of combination with oxygen when the latter is passed over the coke surface. These experiments do not prove whether this is due to the fact:

(*a*) That the chemical affinity between the coke and oxygen is the same in all cases; or
(*b*) that the rate of combination is governed by the rate at which the oxygen can diffuse to the coke surface. If the latter rate is slower than the rate at which the actual chemical combination can take place, diffusion to the coke will be the limiting factor in its combustion.

As the rate of diffusion per unit area of coke will depend solely on experimental conditions, such as the rate of passage of gas, temperature, &c., it will be constant for the different cokes used in Experiments 1-3 and 4-5, and will, therefore, explain the similar behaviour of the "pure" and "Fe_2O_3" and "Na_2CO_3" cokes in these experiments. Bearing in mind the wide differences in the behaviour of the cokes towards carbon dioxide and steam, it appears very probable that the second explanation—viz., that the rate of combustion of the coke at 800° depends on the rate of diffusion of oxygen to its surface—is the correct one.

EXPERIMENTS. SERIES II.

The Combustion of the Special Cokes in Oxygen at Temperatures varying from 300° to 800° C.

The next series of experiments was carried out in order to determine the temperature at which the cokes differed in their rate of combination with oxygen, and also to study their reactivities at low temperatures.

The ignition temperatures of the special cokes in pure oxygen had been previously determined, and are stated in the Eighteenth Report of the Gas Investigation Committee. These determinations indicated that in the temperature range 400° to 600° C. the cokes exhibited very different behaviour. In the following experiments an attempt was made to estimate these differences quantitatively.

Apparatus and Experimental Method.

The apparatus was identical with that used in Series I. In all the experiments the coke surface was 2 cm. long by 1·2 cm. wide. The "O_2N_2 mixture" was passed over the coke through the conduit used in Experiments 4 and 5, Series I., and illustrated in fig. 8, B.

The coke was heated up to 300° C., and maintained at that temperature for one hour. During this period dry nitrogen was passed over the coke to sweep out moisture and any other gases given off by the coke. At the end of one hour the nitrogen was replaced by "O_2N_2 mixture;" the rate of passage of this mixture being in all cases 5 litres per hour (measured at N.T.P.). A sample of the outgoing gas was taken after the "O_2N_2 mixture" had been passing 15 minutes. The temperature indicated by the thermocouple was taken during sampling.

The "O_2N_2 mixture" was then replaced by nitrogen, the furnace raised to 400° C., maintained at 400° C. for one hour, and a sample obtained as before. Samples of gas were obtained in the above manner corresponding with temperatures of 300°, 400°, 500°, 600°, and 700° C.; all these samples being obtained using the same piece of coke. Owing to the small percentages of oxygen in the "O_2N_2 mixture" the six samples could be obtained without much burning-away of the coke surface, the appearance of which after an experiment had not greatly altered. The experiment was repeated using different kinds of coke.

It may be noted here that the temperature indicated by the thermocouple never increased by more than 5° C. when the nitrogen stream was replaced by the "O_2N_2 mixture." As the time taken for the gases to pass from the coke surface to the thermocouple junction was about $\frac{1}{8}$ second, and as therefore the temperature of the gases round the thermocouple will approximate closely to the temperature of the coke surface, this observation substantiates the previous statement that the temperature of the coke surface, when in a mixture of oxygen and nitrogen containing 2 p.ct. of oxygen, does not rise appreciably above the temperature of its surroundings.

The results of Series II. experiments are given in Tables 15 to 19 and graphically in fig. 9.

Table No. 15.—*Combustion of "Pure" Coke 300° C.—800° C.*

Experiment 6. Series II.

Length of coke sample . . . . . 2 cms.
Rate of flow of O_2N_2 mixture . . . 5 litres/hour at N.T.P.
Cross-sectional area of conduit . . . 0·083 sq.cm.
Percentage O_2 in O_2N_2 mixture . . . 1·75 p.ct.

Sample No.	Temperature °C.	"Time of Contact." Second.	Gas Composition (N_2 Free).		
			P.Ct. CO_2	P.Ct. CO	P.Ct. O_2
1	300	0·028	6	4	90
2	405	0·024	8	2	90
3	500	0·021	18	2	80
4	605	0·019	50	20	30
5	710	0·017	70	27	3
6	805	0·015	70	30	0

Table No. 16.—*Combustion of "A. Na_2CO_3" Coke. 300° C.—800° C.*

Experiment 7. Series II.

Length of coke sample . . . . . 2 cms.
Rate of flow of O_2N_2 mixture . . . 5 litres/hour at N.T.P.
Cross-sectional area of conduit. . . 0·083 sq.cm.
Percentage O_2 in O_2N_2 mixture. . . 1·45 p.ct.

Sample No.	Temperature °C.	"Time of Contact." Seconds.	Gas Composition (N_2 Free).		
			P.Ct. CO_2	P.Ct. CO	P.Ct. O_2
1	305	0·028	4	0	96
2	405	0·024	6	1	93
3	500	0·021	9	4	87
4	605	0·019	14·5	3·5	82
5	705	0·017	77	9	14
6	805	0·015	20	71	2
7	615	0·019	19	4	77

Table No. 17.—*Combustion of "Fe_2O_3" Coke. 300° C.—800° C.*

Experiment 8. Series II.

Length of coke sample . . . . . 2 cms.
Rate of flow of O_2N_2 mixture . . . 5 litres/hour at N.T.P.
Cross-sectional area of conduit. . . 0·083 sq. cm.
Percentage O_2 in O_2N_2 mixture . . 1·85 p.ct.

Sample No.	Temperature. °C.	"Time of Contact." Seconds.	Gas Composition (N_2 Free).		
			P.Ct. CO_2	P.Ct. CO	P.Ct. O_2
1	300	0·028	3	1	96
2	400	0·024	8	1	91
3	500	0·021	42	14	44
4	600	0·019	78	19	3
5	700	0·017	75	22	3
6	800	0·015	70	27	3

Table No. 18.—*Combustion of "$CaCO_3$" Coke. 300° C.—800° C.*

Experiment 9. Series II.

Length of coke sample . . . . . 2 cms.
Rate of flow of O_2N_2 mixture . . . . 5 litres/hour at N.T.P.
Cross-sectional area of conduit . . . 0·083 sq.cm.
Percentage O_2 in O_2N_2 mixture . . . 1·85 p.ct.

Sample No.	Temperature °C.	"Time of Contact." Seconds.	Gas Composition (N_2 Free).		
			P.Ct. CO_2	P.Ct. CO	P.Ct. O_2
1	305	0·028	7	1	92
2	400	0·024	4	0	96
3	505	0·021	22	2	76
4	605	0·019	78	5	17
5	705	0·017	94	6	0
6	800	0·015	66	30	4

TABLE No. 19.—*Combustion of "B. Na_2CO_3" Coke.*
300° C.—800° C.

EXPERIMENT 10. SERIES II.

Length of coke sample . . . . . 2 cms.
Rate of flow of O_2N_2 mixtures . . . 5 litres/hour at N.T.P.
Cross-sectional area of conduit. . . 0·083 sq. cm.
Percentage O_2 in O_2N_2 mixture . . 1·45 p.ct.

Sample No.	Temperature. °C.	"Time of Contact." Seconds.	Gas Composition (N_2 Free).		
			P.Ct. CO_2	P.Ct. CO	P.Ct. O_2
1	298	0·028	2·5	2·5	95
2	410	0·024	7	1	92
3	485	0·021	21	4	75
4	603	0·019	42	1	57
5	660	0·017	58	7	35
6	770	0·015	27	70	3

Tables 16 and 19 both refer to "Na_2CO_3" cokes, but they were prepared from two different samples of sodium carbonate, A and B respectively. The only apparent difference between the two samples of sodium carbonate was that sample B was in a much finer state of division than sample A. This difference exercised an effect on the resulting cokes, which, besides differing as shown in fig. 9, also differed in structure; the coke from sample B Na_2CO_3 being finely porous, while the structure of the coke from sample A was much more open.

In the tables of results the gas compositions are stated nitrogen-free. The "time of contact" has the same significance as in Series I. It is seen that it varied with the experimental temperature, this being due to the fact that the rate of flow of the "O_2N_2 mixture," though constant when reduced to N.T.P., varied when measured at the temperature of the furnace. The experiments were carried out in duplicate, the procedure being similar to that outlined above, except that samples were taken at intermediate temperatures in the region where the oxygen was rapidly disappearing. The results of these experiments are not stated, but were taken into consideration when the curves in fig. 9 were drawn.

These curves have been obtained by plotting against the temperature the percentage of oxygen passing unconsumed over the coke. They indicate that the order of the reactivities of the cokes varied at different temperatures.

The iron oxide coke appears to be definitely more reactive than the "pure" coke.

The "$CaCO_3$" coke below 500° C. is less reactive, and above 500° C. is more reactive, than the "pure" coke.

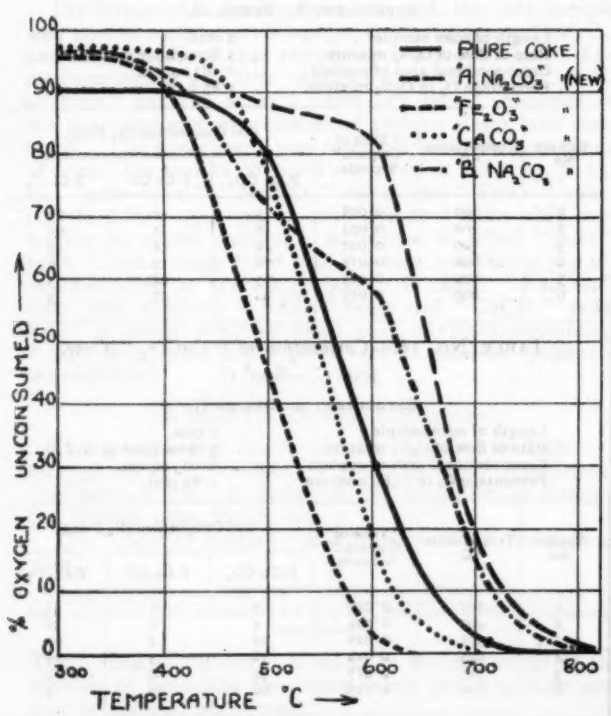

FIG. 9.

coke. The difference between the two cokes is, however, comparatively small.

The curves for both the "Na_2CO_3" cokes are peculiar. It appears to be possible to divide the curves into two portions—the portion below 600° C. and that above 600° C. Both cokes begin to combine with oxygen at 400° C.; the rate of combination increasing very gradually with temperature up to 600° C. The rate of increase in the case of "A Na_2CO_3" coke is smaller than in the case of "B Na_2CO_3." In both curves 600° C. appears to be a critical point; and above this temperature both cokes begin to combine rapidly with the oxygen.

It was thought that this phenomenal behaviour of the "Na_2CO_3" cokes might be due to the fact that the sodium carbonate had, during carbonization, catalyzed the decomposition of hydrocarbons which had deposited an unreactive layer of carbon on the surface of the coke. If this were the cause of the low reactivity below 600° C., the coke should act more normally if this deposited carbon were burnt away. Accordingly, in Experiment 7, sample 7 was taken at 615° C. after the coke had been used to obtain samples 5 and 6 at higher temperatures. Though the surface carbon must have been burnt away during these operations, it is seen that the coke reactivity at 615° C. again fell to the value it had before samples 5 and 6 were taken. The difference in the composition of samples 4 and 7 is small, and can be explained by the difference in temperature at which they were taken. This disposes of the theory that the low reactivity of the sodium carbonate coke below 600° C. is due to deposited carbon.

Above 750° C. all the cokes are sufficiently reactive to combine with all the oxygen passed over them.

The percentage of oxygen which appears as carbon monoxide varies with the different cokes. It will depend on:

(*a*) The proportion of oxygen which initially burns to carbon monoxide with or without the intermediate formation of a carbon-oxygen complex.
(*b*) The opportunities of carbon monoxide already formed of burning in any excess oxygen.
(*c*) The amount of reduction of carbon dioxide to carbon monoxide which takes place. This will depend on the reactivity of the carbon towards carbon dioxide.

From Tables 15 to 19 it appears that:

(*a*) Carbon monoxide forms a considerable proportion of the gases leaving the surface of the iron oxide coke above 500° C. (Table 17), and also from the surface of the "pure" coke above 600° C. (Table 15). The fact that the percentages of carbon monoxide in these two cases do not increase greatly when the temperature is raised to 800° C. suggests that this carbon monoxide is not formed by reduction, as the rate of reduction of carbon dioxide by carbon increases very rapidly with temperature.
(*b*) The "$CaCO_3$" coke (Table 18) gives a maximum proportion of carbon dioxide when the temperature is sufficiently high for the combustion of the carbon to take place, but when it is too low for any extensive reduction of carbon dioxide to carbon monoxide.
(*c*) At temperatures above 750° C. the percentage of carbon monoxide in the gases leaving the "Na_2CO_3" coke is high. This carbon monoxide appears to have resulted from the reduction of carbon dioxide by the coke.

Summing up the results obtained in experiments in Series I. and Series II., one can conclude that:

(1) There are wide differences in the behaviour of the cokes towards oxygen at temperatures within the range of 400° to 700° C.
(2) Above 750° to 850° C. the differences between the cokes appear to vanish under the experimental conditions described.
(3) There is no connection between the reactivities of coke towards oxygen at low temperatures and the reactivities at high temperatures.

Thus it seems that a determination of the ignition temperature of a coke does not give much information applicable to high temperature working conditions.

In suggesting that the similarity of the rates at which the special cokes react with oxygen above 800° C. can be explained by the theory, outlined by Haslam and Russell, that at high temperatures the rate of combination of coke and oxygen is governed by the rate of diffusion of oxygen to the coke surface, it must be remembered that in the experiments described above the coke was burnt in an atmosphere containing only 2 p.ct. of oxygen. In such an atmosphere the rate of diffusion of the oxygen to the coke surface will only be one-tenth the rate of diffusion when the coke burns in normal air. As a result, the effect of the "diffusion factor" will be accentuated; but from consideration of the rapid rate at which the speeds of chemical reactions increase with temperature, the effect of diluting the air with nitrogen on the temperature above which all cokes behave similarly will not be great.

In the above experiments the reactivity of the cokes has been obtained by using a surface with practically no covering of ash on it. Generally, however, at the base of a fire the proportion of ash to combustible matter may be relatively high. This ash may have an appreciable effect on the rate at which oxygen can diffuse to the carbon; and this fact should be considered in the interpretation of the above results.

EXPERIMENTS. SERIES III.

The next series of experiments was carried out to investigate the readiness or otherwise with which different cokes would heat up when a stream of air was passed through them under standard conditions.

Experimental Method.

Ten grammes of the coke under investigation, ground to pass $\frac{1}{8}$ in. and remain on $\frac{1}{10}$ in. mesh sieves, rested on fireclay blocks in a Morgan reaction tube which was supported vertically in an electric furnace (fig. 10). The internal diameter of the Morgan tube was 2·2 cm., and 10 grammes of coke of the above grade formed a column about 6 cm. in length.

The sheath of the thermocouple passed through the coke column; the junction of the couple being arranged to be 2 cm. below the surface of the coke. Air, contained in a gasholder, passed through calcium chloride tubes and flow gauge, and then entered the Morgan tube at the top.

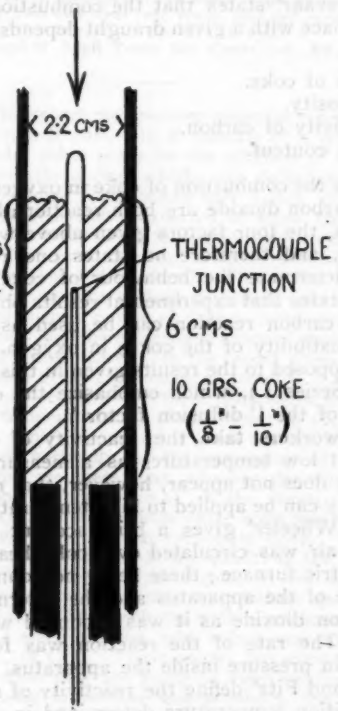

FIG. 10.

In the carrying out of an experiment, the coke was raised to a temperature of 700° C., and maintained at that temperature for one hour, no gas being passed through the furnace during this period. When it had been found how many amperes must pass through the furnace to maintain it at 700° C. in this condition, these amperes were maintained constant throughout the remainder of the experiment.

After the coke had been at 700° C. for one hour, dry air was passed downwards through the coke at a rate of 50 litres per hour. The temperature registered by the thermocouple was then read every 2½ minutes until a maximum temperature had been passed.

After the experiment it was found that most of the coke had been burnt away.

The experiment was carried out using:

(*a*) "Pure" coke, carbonized at 800° C.
(*b*) "Pure" coke, carbonized at 1100° C.
(*c*) Beehive coke.
(*d*) "Na_2CO_3" coke.

The results are shown graphically in fig. 11, where the temperature registered by the couple is plotted against the time measured in minutes from the point when the air passage was started. From this graph it is seen that the maximum temperature attained varied with the different cokes—*e.g.*,

Experiment No.	Description.	Maximum Temp. °C.
18	Beehive coke . . .	980
19	"Pure" coke 1100° C.	940
20	"Pure" coke 800° C. .	940
21	"Na_2CO_3" coke . .	865

Samples of the outgoing gases were not taken in these experiments, as, owing to condensation of moisture in the sampling device, it had to be removed from the apparatus. It is plain, however, that the cokes in the table just given are in the ascending order of their reactivities towards carbon dioxide, the beehive coke having the lowest, and the "Na_2CO_3" coke the highest reactivity. This connection between the maximum temperature attained by the cokes and their carbon dioxide reactivity can be explained by the fact that the oxygen of the air first combines with the carbon of the coke to give carbon dioxide, which is then in part reduced by the carbon to carbon monoxide. The extent of the reduction of the carbon dioxide to carbon monoxide will be greatest in the case of the coke with the highest reactivity towards carbon dioxide. As this second reaction is endothermic, it will render latent some of the heat given out by the combustion of the carbon to carbon dioxide, and so less heat will be available to heat up the coke column.

Thus these experiments indicate that in industrial operations where high temperatures are required in a bed of fuel—*e.g.*, in foundry work, blast furnace hearths, and the "blow" of a water gas plant, &c.—a coke with a low reactivity towards carbon dioxide will be more suitable than a coke with a high carbon dioxide reactivity.

In other instances, however—*e.g.*, in the open fire—the free-burning quality of the fuel assumes greater importance.

The Work of Others.

The amount of work which has been carried out with special reference to the ash constituents in the reaction between coke and oxygen is small; and the following account is a general summary of the work done on the combustibility of cokes in air or oxygen.

Bahr[1] passed a stream of oxygen or air through a definite volume of granulated coke, and analyzed the issuing gas. The temperature of the coke column used was 850° to 950° C. The analyses of the gas samples showed that at these temperatures only traces of oxygen passed through; the gas consisting of a mixture of carbon dioxide and carbon monoxide (*plus* nitrogen if air was used) which had the same composition as the gas obtained by streaming carbon dioxide through the coke under the same conditions. Thus these experiments do not appear to be a measure of the rate of combustion of the coke in oxygen, but indicate only its reactivity towards carbon dioxide; the latter being rapidly generated at the front end of the coke column, and then being in part reduced by further passage through the hot coke. The results showed that the $CO : CO_2$ ratio was appreciably increased by the presence of iron or iron oxide in the coke.

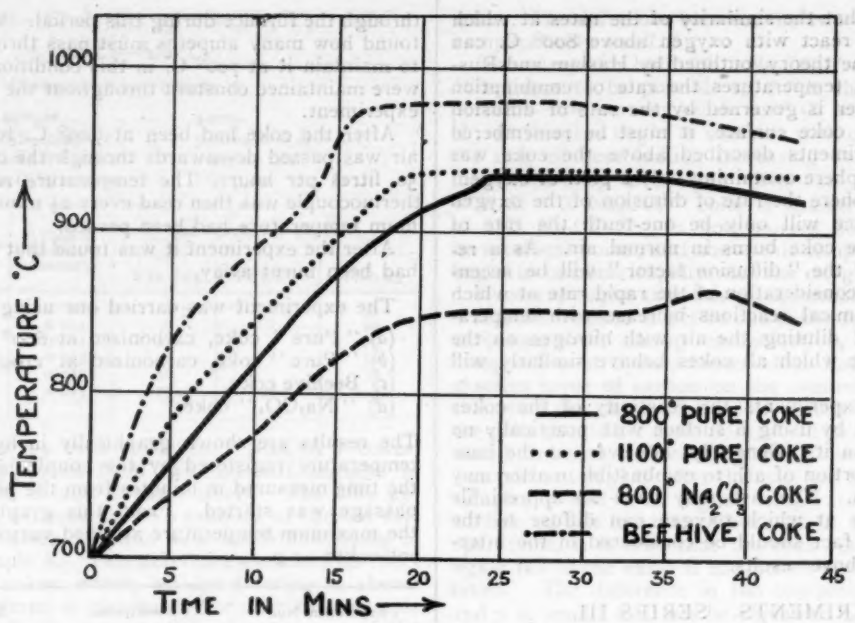

FIG. 11.

R. A. Sherman and S. P. Kinney[2] gave an account of work in which the combustibility of cokes was determined in the laboratory by streaming oxygen over a boat containing a definite weight of granulated coke at a definite temperature. The loss in weight of the coke after a given time was taken as a measure of its reactivity. They themselves criticize the method as not giving a true indication of the combustibility due to the fact that, as the combustion of cokes is a surface phenomenon, the surface of the coke, and not the weight, should have been standardized. With reference to the above test, Haslam and Russell state in their book "Fuels and their Combustion":

> This test measures the rate of oxidation of the cokes which depends on the rate of diffusion of the oxygen to its surface. Therefore, the combustibility of coke as measurd by this test depends on the velocity of the oxygen and upon the area of the surface of the coke. As would be expected all cokes show practically the same combustibility by this test.

Sherman and Kinney also describe a salamander test. Graded coke is contained in an experimental furnace with a fuel bed 12 in. deep, and air is passed through it at a definite rate. The progress of the reactions occurring were studied by taking samples at various heights up the fuel bed. The combustibility was measured by the loss in weight of the fuel bed in a given time.

Koppers[3] introduced a modified form of this test by substituting the character of the flame above the fuel bed for the loss in weight as the measure of combustibility. In this test, the longer the flame the more combustible the coke.

A further modification was made by Korevaar[4], who varied the depth of the fuel so that all cokes gave a flame of the maximum possible size for a given rate of air flow. The minimum depth of the fuel bed necessary was taken as an indication of the combustibility. The deeper the fuel bed necessary, the smaller the combustibility of the coke.

These salamander tests, like the test given by Bahr, really do not measure the speed of the reaction between coke and oxygen, but measure the rate of reduction of carbon dioxide by the coke.

Sherman and Kinney, in summing up the result of their work, said: "The results of the investigations show that coking time, specific gravity, porosity, the volatile matter, and the coking temperature have no great influence on the rate of combustion of coke in oxygen. They show that only the size of the pieces of the coke has any material effect on its combustibility, and that this effect is very marked; small coke giving a more compact and hotter zone of combustion than large coke. Such variations as were found in similar sizes of various cokes were so slight that, in the light of the theories as to the effect of combustibility, it is improbable that they would make any material difference in furnace operation." They point out, however, that the tests were not decisive, since the relative combustibilities of various cokes might, under working conditions, be different from those of their experiments; and they came to the conclusion that it was extremely difficult to formulate laboratory tests for the combustibility of coke such that the results obtained could be extended to working conditions. Thus they tested the suitability of cokes for blast furnace purposes by carrying out experiments under actual working conditions. They took samples of gas from blast furnaces at various heights above the tuyeres. They could not find any variations with different cokes.

L. Korevaar[4] states that the combustion of coke in a given furnace with a given draught depends on four factors —viz.:

(1) Size of coke.
(2) Porosity.
(3) Activity of carbon.
(4) Ash content.

Also, as the combustion of coke in oxygen and its oxidation by carbon dioxide are both reactions between a solid and a gas, the four factors given above will govern both reactions; and therefore he states one reaction can be used to determine the behaviour of cokes in the other. Thus he states that experimental results obtained by using the CO_2: carbon reaction can be used as indications of the combustibility of the cokes in oxygen. This view is directly opposed to the results given in this paper (Experiments. Series I.), which emphasize the dominating importance of the "diffusion factor."

Other workers take the reactivity of cokes towards oxygen at low temperatures as a measure of combustibility. It does not appear, however, that results obtained in this way can be applied to high temperature working.

R. V. Wheeler[5] gives a brief account of experiments in which air was circulated over coke heated to 400° C. in an electric furnace; there being no connection between the inside of the apparatus and the external atmosphere. The carbon dioxide as it was produced was absorbed in potash. The rate of the reaction was followed by the decrease in pressure inside the apparatus.

Bunte and Fitz[7] define the reactivity of a coke in terms of its ignition temperature determined in air under standard conditions.

E. V. Evans described a method for measuring the combustibility of coke at the Sheffield Coke Conference, 1925. A 5 in. diameter circular iron Büchner funnel was used as a grate, and was partially filled with graded firebrick of gradually decreasing size, topped by a layer of coke 10-20 mesh. A standard air current was drawn through the fuel bed which was then ignited at one point by a

small gas flame. The zone of combustion spread out from this point at a rate which was measured; and this rate was taken as an indication of the combustibility. The rate of travel of the zone of combustion must depend to a large extent upon the ease of ignition of the sample under investigation.

Le Chatelier, in "Le Chauffage Industriel," gave a method for determining the combustibility of carbon. Granulated carbon was heated in a porcelain tube to 150° C. A current of air was then passed over it at a definite rate. According to the degree of combustibility different phenomena were observed. In the case of slow burning carbon the temperature fell when the air was passed. If the carbon was of average combustibility, the temperature rose more or less above 150° C., and became fixed at a new constant temperature, whereas if the carbon was very combustible the temperature rose rapidly until the carbon was burning freely.

Though the method of carrying out these experiments was very similar to that used in our experiments, Series III., owing to a difference in the experimental temperature the results are entirely different, and cannot be compared. Thus in Le Chatelier's experiments reactive cokes give the highest temperature and unreactive cokes the lowest, whereas in our experiments described above the highest temperature obtained was with a beehive coke which normally would be classed as very unreactive. The behaviour of a coke in Le Chatelier's experiments appears to be largely governed by the position of the ignition point relative to 150° C.

Hodsman and Bligh[8] compared the behaviour of various cokes in an open fire grate. Among the cokes tested was one which had been impregnated with sodium carbonate. This treated fuel was found to burn very rapidly, and long flames of carbon monoxide blazed 18 in. above the fuel bed. This fuel was also remarkable in that it burned practically to completion leaving only a small amount of ash and cinder in the grate.

REFERENCES.

[1] H. Bähr, Stahl und Eisen, **44**, 1-9, 39-42, 1924.
[2] R. A. Sherman and S. P. Kinney, "Fuel in Science and Practice," **5**, pp. 98-105.
[3] Konners, Stahl und Eisen, p. 560, 1922.
[4] A. Korevaar, "Combustion in Blast Furnaces and Gas Producers."
[5] L. Korevaar, "Fuel in Science and Practice," **5**, pp. 92-97, 1926.
[6] R. V. Wheeler, J. Iron and Steel Inst. No. 1, 1923, pp. 75-78.
[7] Bunte and Fitz, "GAS JOURNAL," pp. 167-513, 1924.
[8] H. J. Hodsman and M. Bligh, Trans. Soc. Chem. Ind., **46**, 92-99T.

Prof. COBB: The report we are now going to consider is the Gas Fellowship 1927 Report, and it consists of a study of the behaviour of special cokes made by the addition of certain inorganic constituents to a coal which was deliberately chosen for the purpose because it contained only 1 p.ct. of ash, and might therefore be reasonably expected to allow the effect of the additions of each constituent to display itself to the full. I refer to fig. 2 of the report as being illustrative of some of the points which are elaborated in detail. There, the pure coke, the iron oxide coke, and the sodium carbonate coke have been compared as regards their power of decomposing steam at different temperatures, and therefore their rates of gasification in steam at different temperatures. In the report given last year, there were indicated great differences at 1000° C.; and it was thought desirable to see how far these differences extended to other regions of temperature. I simply want to pick out one illustration. The centre line of fig. 2 gives the results obtained at 800° C., plotted vertically, as the percentage of steam decomposed; and you see there that, whereas the coke without additions decomposed about 12 p.ct. of the steam, it became round about 25 p.ct. when the iron oxide coke was used, and nearly 95 p.ct. with the sodium carbonate coke. The same sort of difference was noticeable in the quality of the water gas made by the decomposition of the steam, in the sense that, whereas with the pure coke at that temperature the gas was rich in CO_2 and low in CO, with the sodium carbonate coke it was nearly all CO and hydrogen, with only a very small quantity, about 1 p.ct., of CO_2. These results are extremely striking. Regarding what they are going to mean applied in practice, I am not going to venture any prophecy, but that they must have a meaning, and a very important meaning, is, I think, obvious. When we consider the enormous importance which attaches to the comparatively small differences in the reactivity of coke brought about by different methods of carbonization, and then compare them with the enormous differences brought about in this sort of way, surely there is going to emerge some method of controlling the properties of coke by some such system as is suggested as a possibility here.

I may say that the original experiments were made more particularly in order to study the influence of the ash constituent as one factor among a number of other factors in influencing the results obtained. The influence of the ash will always remain one factor among others; and what has emerged so far is the enormously greater quantitative importance which seems to attach to this factor than I, at any rate, had considered to be reasonable or possible, and it seems to justify a very full and complete study of the whole subject. This is responsible for the first of these three papers in the report, which represents an extension of the work as regards reactivity to steam. This has been carried out by Mr. Sutcliffe, who succeeded Dr. Marson as Gas Research Fellow. Then, considering the great importance in producer work, furnace work, and fires generally of the reaction with CO_2, this obviously could not be left on one side. It was started by Mr. Branson last year, and has been carried further by him, and is detailed in Part II. of the report. Another branch of the work to which I will refer later has been in connection with reactivity to air or oxygen, the importance of which is so obvious that I need not stress it just now. As regards reactivity to steam, Mr. Sutcliffe extended the work to other temperatures, as I have just described; but there were other things to take into account. In the first place, what is the result, supposing one takes for granted that such a figure as 5 p.ct. is not to be regarded as practicable for purposes of additions, if small quantities are used? A certain amount has been done in this connection; and I need only say as a rough summary that the proportionate effects of smaller additions are greater. What I mean is that 1 p.ct. will give far more than one-fifth of the effect of 5 p.ct. This generalization can be made with complete safety. Again, it was found in connection with the alkalis that other sources of alkali such as sulphate of soda seemed to be to all intents and purposes as effective as the more expensive carbonate of soda. I think I will leave the other things in connection with steam to be dealt with by Mr. Sutcliffe, who will follow me, and just mention this additional point that it was always possible in a reaction of this sort that some special virtue might attach to the mixtures of oxides. This was looked into; but so far as we can see, any special virtue was not present. The effects were more or less additive of the individual oxides when they were used in admixture.

The differences in reactivity in CO_2 as compared with the pure coke are just as marked, and in some cases even more so. The phenomenon here which requires more investigation is the falling-off in reactivity with time. The initial reactivity is always very high. This has been followed up in some detail by Mr. Branson. With the sodium carbonate there is a falling-off; and this requires further explanation. I may say that the same falling-off does not take place with steam. There is practically no falling-off with steam; but there is a falling-off with time in the case of the sodium carbonate coke. With the iron oxide coke, the explanation of it does seem to have been arrived at, I think, because if the iron oxide coke is treated with hydrogen, or is heated for some time alone in an inert atmosphere with nitrogen, after the falling-off has occurred, the initial reactivity is regenerated. It is plain, I think, that the oxide of iron does directly come into play—the oxide of iron and the metallic iron which is formed by reduction of the oxide of iron added.

Leaving this to Mr. Branson, I would like to say something about the reactivity towards air, which is a branch of the subject we have not touched until this year, and the experimental work in connection with which has been carried out by Mr. Dent with great skill. Unfortunately he is not able to be present this morning. The difficulty of investigating the comparative reactivities of coke with air arises largely from the fact that the amount of heat generated is so considerable that it becomes extremely difficult to work at the temperature, and determine the reactivity at that temperature, because, as soon as the reaction with air starts, the amount of heat generated is so considerable that the temperature begins to soar. This difficulty has been overcome by using instead of air a mixture of air and nitrogen containing only about 2 p.ct. of oxygen, by this means getting a much less intensified combustion. Instead of using the material under test in the form of a column of powdered coke, a small surface of coke having an area of about 1 sq. cm. was employed, and over this small area the stream of nitrogen diluted air was passed. The method of doing this is described in detail, and is illustrated in the report. Preliminary experiments showed, sighting with a pyrometer on the surface of the coke, that the generation of heat can be controlled to such an extent that the temperature does not rise by more than 5°, and therefore quantitative experiments and observations can be carried out giving a variety of reactivities at a pre-determined temperature. Experiments having been done in this way, the comparison was made at a temperature of (say) 800° C., and it was found that, with air, no differences between the cokes were noticeable. What it really meant has been pointed out before, but is confirmed by this work. As soon as you get to a temperature of that nature, all the cokes are so far reactive that they burn up all the oxygen supplied to them; and consequently the determining factor is the supply of oxygen. If this is made the same as it was in these experiments for the different cokes, the results obtained are substantially the same. This condition of affairs exists at a temperature of 800° C. even when there is a rapid passage of the

nitrogen diluted mixture. Similar tests at lower temperatures from 300° up to 800° C. were made; and these established that from 700° downwards definite differences could be determined. It was possible to draw curves showing the comparative reactivities at the different temperatures.

There are some anomalies in the case of sodium carbonate coke which require further study. This offers a number of points of interest which have already given us some further experimental results, which are not included in the report because the subject is one that is better reserved for separate treatment. Another interesting point that was brought out experimentally, but which offers no difficulty in understanding, can be seen as regards the experimental apparatus in fig. 10, where an arrangement is shown of a thermo-couple embedded in coke, air being passed downwards through it. The results obtained with different cokes are shown in the report, which indicates that when using air the greatest rise in temperature occurred with a hard non-reactive beehive coke, and the worst rise in temperature occurred with the most reactive coke. The meaning of this apparent anomaly, of course—there is no difficulty in the explanation—is that in each of these cases the amount of heat generated will be the same, dependent upon the air supply; but in the interior of the mass the generation of heat is followed by an absorption of heat consequent upon the reduction of the CO_2 first produced, by the carbon, to CO. That reaction absorbing heat is very much more pronounced in the case of these very reactive coke; and, therefore, the heat absorption being greater, the temperature is lower for the more reactive than it is for the less reactive cokes.

Mr. SUTCLIFFE then gave an abstract of Part III. (*a*) of the report.

Mr. BRANSON followed with an abstract of Part III. (*b*) of the report.

Discussion.

The PRESIDENT: If you would be good enough to put any questions to Prof. Cobb, it will save time. He has promised to be good enough to reply in writing; and his replies will appear in the Technical Press. The reactivity of coke, of course, is equally important to the gas undertakings themselves as to any other industry, and equally important to gas undertakings as it is to the consumers of coke for domestic purposes. However, as time is extremely limited I am afraid I shall have to content myself with formally moving the adoption of the report.

Mr. J. FERGUSON BELL (Derby): I have much pleasure in seconding the adoption of this report. It occurs to me that this question of the reactivity of coke is well worth investigation in respect of water gas plants, in which we use a large quantity of coke; and the reactivity of that coke has an important bearing on the quality of the gas produced. From these investigations it would appear that it is not always the purest coke which is the most active or which gives the best results; and I should like to ask Prof. Cobb what his opinion is with reference to a coke with a large percentage of inerts such as ash and sulphur. What effect would that have in the production of water gas? We are all vitally interested in this question of coke, not only from the user's point of view, but as makers of water gas and sellers of coke to domestic consumers; and I do not think we can attach too much importance to the subject, in order that we may produce a coke which will give the very best results when used in domestic appliances. In seconding the adoption of the report I should like to express our indebtedness and our thanks to the Investigation Committee for the great care with which they place these very valuable results before the Institution.

Mr. CLARENCE HARRIS (Taunton): The research work indicates that with certain cokes a small addition of alkali salts makes the cokes more reactive for the decomposition of steam, although for combustion with air the difference is not so noticeable. An excellent method of impregnating coke with the alkaline salts has been indicated by the suggestion that the coke might be quenched by a solution of the salts in question. For continuous vertical retorts, however, this method is inapplicable, as the cooled coke would not absorb water to any extent, and it appears to be impracticable to crush the coal before carbonization to obtain an intimate mixture with the alkaline salts, as this would reduce the throughput of the retort very materially. I would like to know if, in view of the greater value of such prepared coke for water gas manufacture, Prof. Cobb would indicate any practical method of preparing impregnated continuous vertical retort coke. I should like to know if the coke is crushed.

Prof. COBB: It was in these experiments.

Mr. HARRIS: Then that will make it very difficult for us to get the results in time.

Prof. COBB: I do not think that would necessarily be the case, but the details of the best quenching method would have to be worked out.

Mr. J. FERGUSON BELL: We have found that in using coke from vertical retorts for making carburetted water gas we were not able to get anything like such good results as with the coke from horizontal retorts.

Dr. E. W. SMITH: It is not fair to look to the Leeds University for panaceas for enabling us to get rid of coke. After they have done all they can, and after they have shown us what causes the differences between the reactivities of different cokes, everything that they do, or everything that is adopted as the result of what they do, will be entirely neutralized unless coke is properly dried and graded for the purpose for which it is required. This can be done at once, without waiting for Leeds University, by a large number of gas undertakings which are not attempting to do so to-day.

Mr. R. ROBERTSON (Bristol): May I ask what Prof. Cobb considers would be the effect on the fireclay of adding such a constituent to the coke as iron oxide?

The report was then adopted.

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COKE COOLING.

By JOHN P. LEATHER, M.Inst.C.E.

Most of those responsible for the conduct of gas-works are familiar with the wonder and admiration expressed by strangers who visit the works, when they witness the discharge of incandescent coke from a retort. The intense heat and the clouds of steam arising when water is thrown on the coke make an impressive sight. Notwithstanding the adoption in many cases of continuous-working vertical retorts, this scene is still a frequent one. When the economy of the process is analyzed, it seems strange that there should be so little change after a hundred years of gas making.

The distribution of heat in a retort setting has been the subject of various researches, and we know that very little heat is absorbed by the carbonization of the coal; some portion of the process having, indeed, been shown to be exothermic.

Of the heat applied, some 15 p.ct. to 20 p.ct. is carried away by the hot gases leaving the retort. Even with regenerative furnaces 25 p.ct. to 30 p.ct. passes away in the products of combustion. The heat lost by radiation and convection from the setting often amounts to 25 p.ct. The heat used in raising the coke to the temperature of carbonization and which remains in the coke when it leaves the retort account for a further 25 p.ct. Waste-heat boilers have been introduced with more or less success to deal with the heat in the chimney gases, and insulating bricks are being used to reduce the radiation losses, but except in continuous verticals little has been done in this country to recuperate the heat in the coke.

There is, moreover, in the usual treatment of hot coke not only a great loss of potential energy, but the sudden cooling of the coke by water is damaging to the quality of the coke. The contact with the water tends to disintegrate the coke by the explosive formation of steam, to blacken the appearance, destroying its lustre, and to diminish its reactivity, making it more difficult to ignite, while by the introduction of moisture the calorific value is reduced.

Experience at Liverpool.

To obviate these disadvantages a process of dry quenching was installed by the late Mr. Edward Allen at the Linacre Works of the Liverpool Gas Company. The coke was pushed from the retort into an iron receptacle of similar shape and dimensions to the retort itself. This receptacle was held by a telpher in line with the retort during the process of discharging. It was then closed by an airtight door and carried to a tank of water in which it was deposited. When cool it was taken out and emptied. There was a remarkable difference in the appearance of the coke cooled in this way without contact with water, when compared with coke from the same retorts quenched in the usual manner. The process was not economical, but the results encouraged further experiments which have been continued by Mr. R. E. Gibson as described in his paper to the Institution in 1924 on "The Construction of New Coal-Gas Works at Garston." In these the coke is deposited by a "G.N" hot coke handling machine into a coke container surrounded by a water jacket. Improvements in the construction of the water jacket have been introduced since 1924 tending to greater economy in water: and the water thus heated is utilized for boiler-feeding. By the courtesy of Mr. Gibson I am able to exhibit samples of coke, dry and wet quenched.

Other Methods.

The purpose of this communication is to describe three types of plant for the quenching of hot coke, which the author has investigated, and to discuss the theoretical and practical considerations involved, in the light of experience.

The Sulzer System.

The most important of these from the point of view of length of experience and range of application is that of the Swiss firm, Messrs. Sulzer Bros., of Winterthur. This system is in use in gas-works in Switzerland, Germany, Holland, and America, as well as in a number of coke oven plants.

A section of the first plant installed at the Keilehaven Gas-Works, Rotterdam, is shown in fig. 1. A general

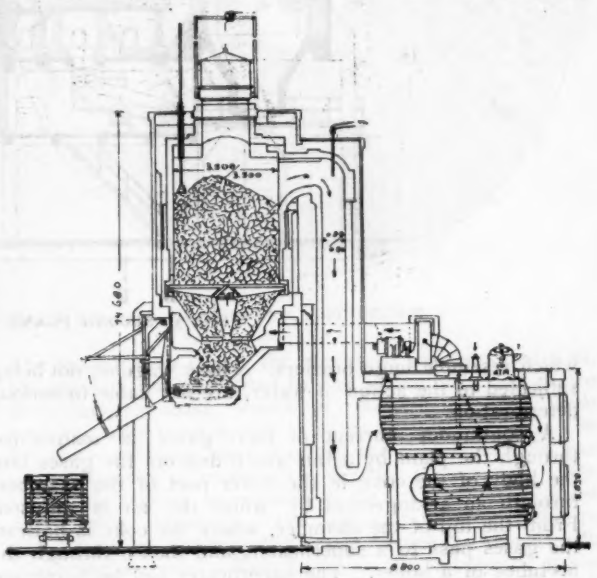

FIG. 1.—FIRST PLANT AT KEILEHAVEN, ROTTERDAM, 1922.

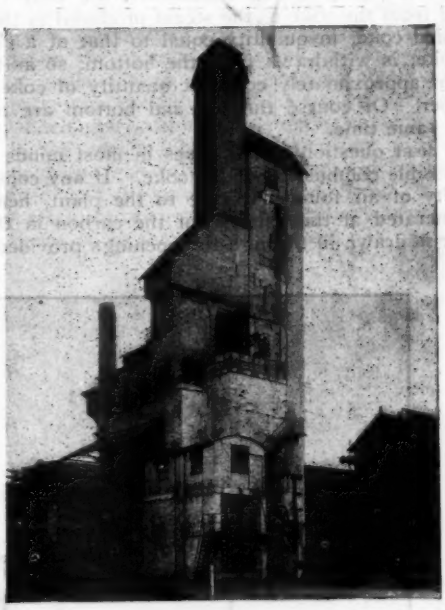

FIG. 2.—KEILEHAVEN 1.

view of the same plant is seen in fig. 2. Fig. 3 gives a section of the larger plant since erected in connection with the large addition to the works. Fig. 4 is a view of the new plant with the first one in the background. The construction of the plant is of concrete lined internally with firebrick. The opening at the top of the cooling chamber for the introduction of coke is closed by a water-sealed hood constructed of aluminium plate. This hood is automatically raised by the lift which elevates the wagon containing the hot coke. The movement of the lift also inserts a chute into the opening, and discharges the coke from the wagon.

The wagons employed for the hot coke are constructed of iron bars fitting closely together—a contrast with the open-work skips so often seen in English gas-works,

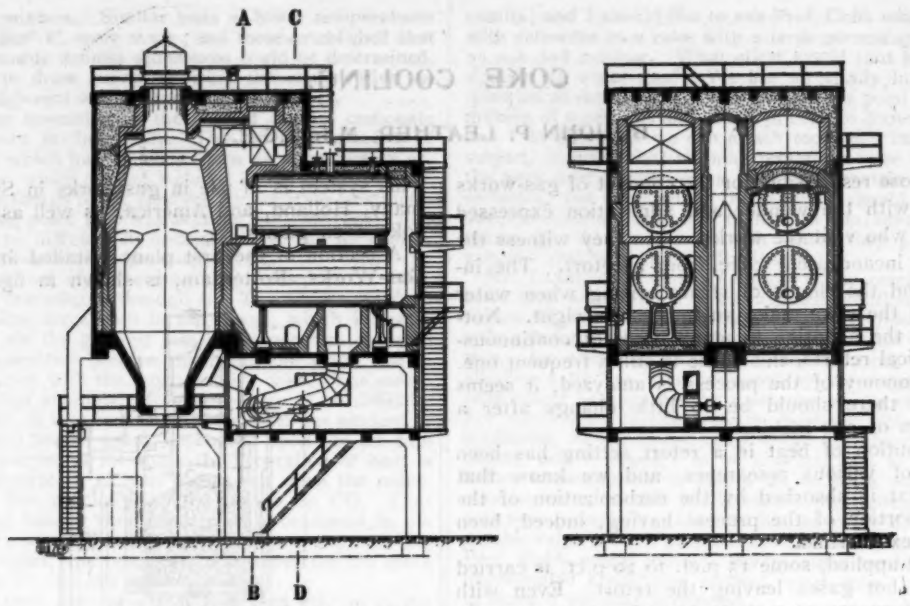

FIG. 3.—SECOND PLANT AT KEILEHAVEN, ROTTERDAM.

which resemble huge braziers. These wagons, not being subjected to the action of water, are not liable to serious deterioration.

A continuous current of inert gases is maintained through the plant by a fan which delivers the gases into the body of the coke in the lower part of the chamber, through an arrangement by which the air is diffused. From the top of the chamber, where the coke is hottest, the gases pass to a superheater, and thence through the firetubes of a boiler. The superheater can be by-passed when desired. After passing round the boiler, they return to the fan, having transferred the heat they had gained from the coke to the steam produced in the boiler.

Cooled coke, in quantity equal to that of a charge of hot coke, is withdrawn from the bottom, so as to maintain an approximately constant quantity of coke in the chamber. Of course the top and bottom are not open at the same time.

The first question which arises in most minds is as to the possible combustion of the coke. If any considerable quantity of air found entrance to the plant, heat would be generated at the expense of the carbon in the coke. No air is drawn in through the openings provided for the entrance and withdrawal of coke, as normally there is a pressure, in the Keilehaven No. 2 plant, of about 2½ in. of water. This is diminished after passing through the coke to less than 5-tenths of an inch at the top of the coke container. There is a neutral point of level gauge between the superheater and the boiler or shortly after entering the boiler tubes. After this point the pressure is less than that of the atmosphere, until at the inlet of the fan there is a suction of about 2 in. During the brief periods when the hood is lifted for the admission of hot coke, the pressure diminishes by 2 or 3 tenths, and by about 8 or 10 tenths during the discharge of cooled coke. The difference of pressure between inlet and outlet of fan is unaffected by the opening of the doors, but is slightly increased by the extra resistance of additional coke, and reduced when the depth of coke is decreased. These changes of pressure are shown on the charts reproduced (fig. 5).

The temperature of the gases leaving the coke container depends on the temperature of the coke supplied and the frequency of the charges of hot coke. With coke at 1900° Fahr. it may reach 1300° to 1400° Fahr. after fresh coke is introduced, falling 200° to 300° or

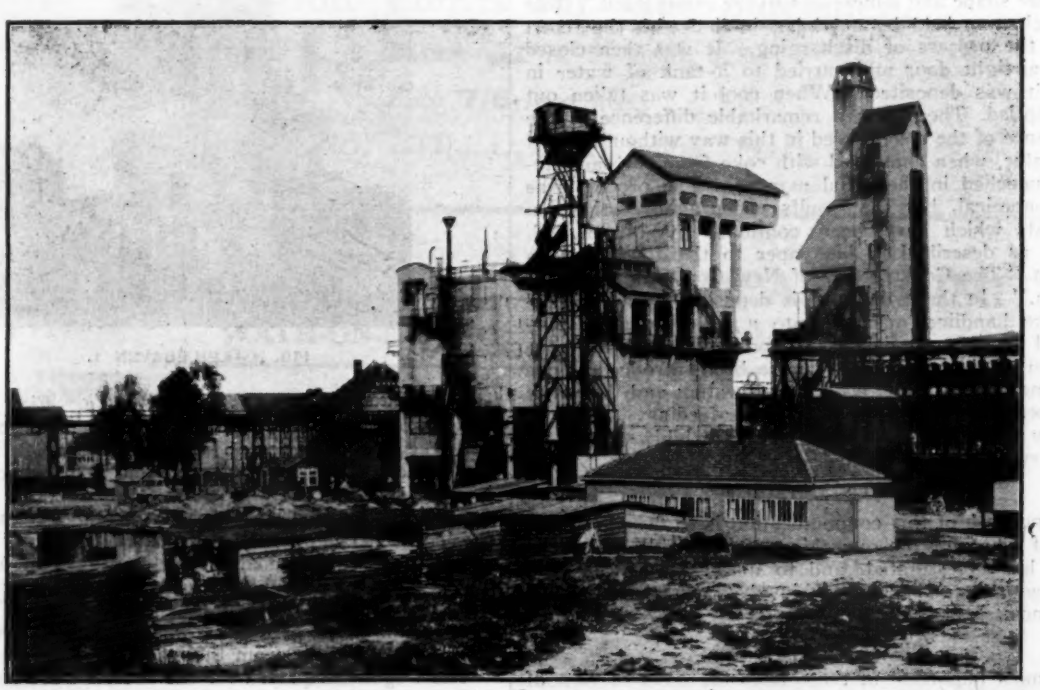

FIG. 4.—KEILEHAVEN II.

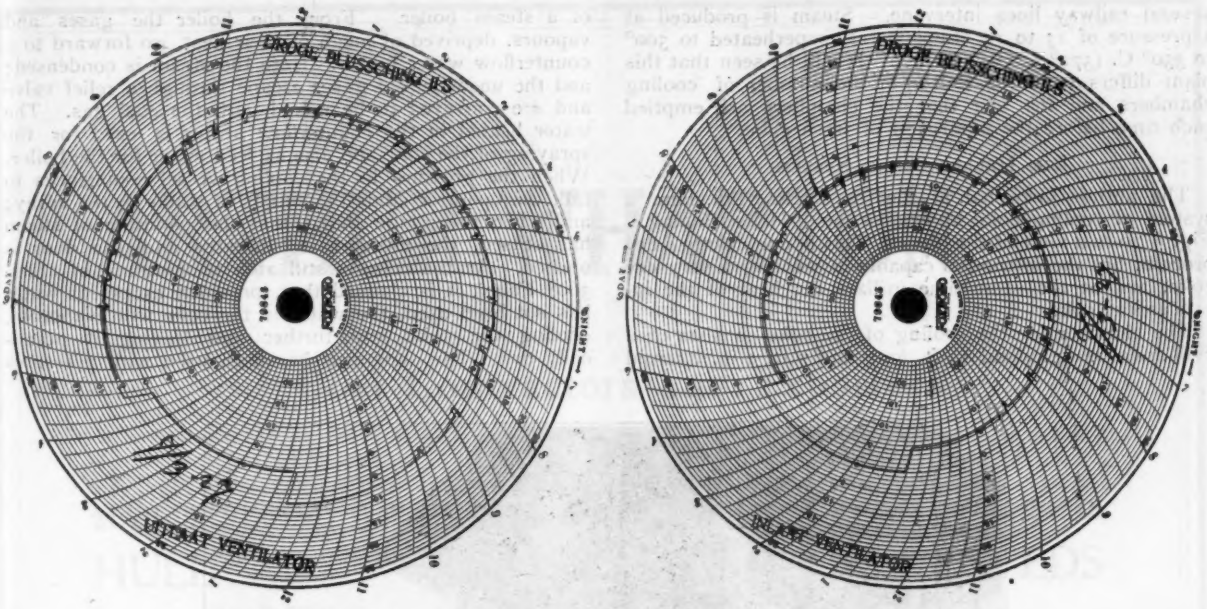

FIG. 5.—PRESSURE CHARTS AT INLET AND OUTLET OF FAN, KEILEHAVEN, ROTTERDAM.

more before the next charge. At the inlet of the fan the temperature is about 400° Fahr. with a boiler pressure of about 12 atmospheres. This is not a waste gas temperature, but it constitutes a limit below which the coke cannot be cooled. The whole of the difference in the quantity of heat in the coke between entering and leaving the plant is recovered in the form of steam except that which is lost by radiation and convection from the outer surfaces of the apparatus. This loss can be made very small by suitable construction and the use of insulating material.

The arrangement at the Utrecht Gas-Works (fig. 6) differs from the installations at Rotterdam in the boilers, which are water-tube in place of fire-tube. The plant is in duplicate, each section being capable of dealing with 150 tons of coke in 16 hours. Steam is produced at a pressure of 13 atmospheres and a temperature of 360° C. (680° Fahr.).

THE COLLIN SYSTEM.

The principle on which this process works is the same as that of the Sulzer, in that the heat of the coke is transferred to steam boilers by the agency of inert gases. The system is in use at the municipal gas-works at Kiel, but the installation visited by the author was that of the Henrichshütte coke works at Hattingen. This deals with the coke from a battery of 50 chamber ovens. The hot coke, on being pushed out of the chambers, falls into one of a series of receptacles in which it is cooled. One receptacle (shown in section in fig. 7) serves for three carbonizing chambers. The top and bottom openings are closed by water-sealed doors, which are lined with insulating material. Two flues run the full length of the battery, one to bring the circulating gases from the fan in the boiler house, and the other to return the hot gases through the boilers back to the fan. These flues are connected to the cooling chamber by sand-sealed valves. The coke in the chamber rests on an incline formed of cast-iron plates placed at an angle of about 42°. The gases enter the coke by the interstices between these plates. Each charge of coke, weighing about 8·3 tons, remains in the cooling chamber about four or five hours, after which the gas valves are closed, the bottom doors are opened, and the coke is removed, being conveyed by a transporter conveyor direct into railway wagons. The boiler house is at some distance from the chambers, as

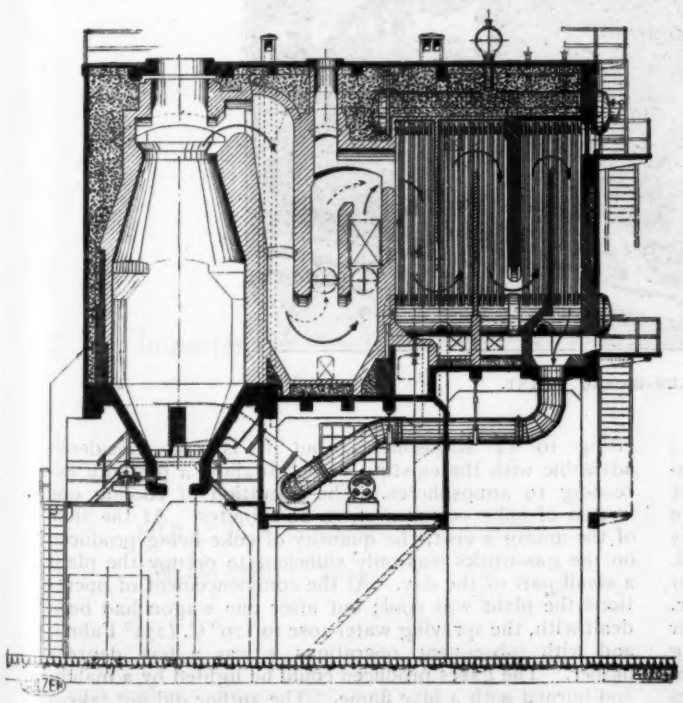

FIG. 6.—SECTION OF UTRECHT PLANT.

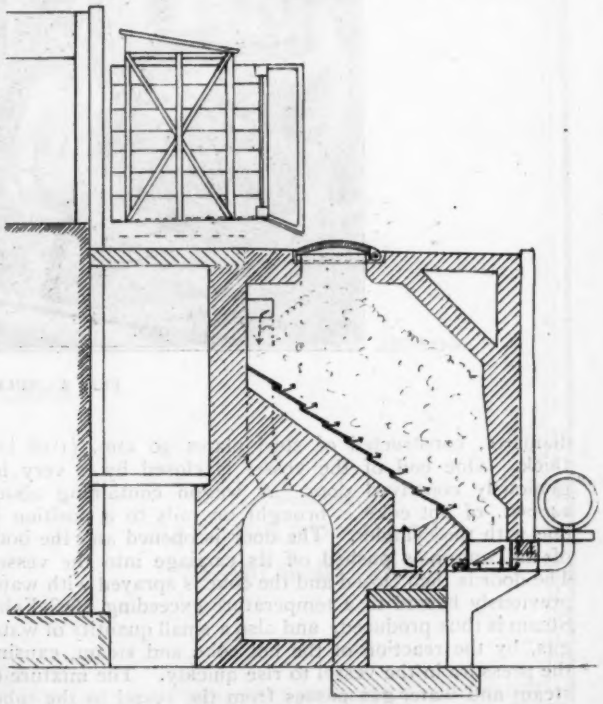

FIG. 7.—COLLIN PLANT.

several railway lines intervene. Steam is produced at a pressure of 13 to 14 atmospheres, superheated to 300° to 350° C. (572° to 662° Fahr.). It will be seen that this plant differs from the Sulzer in the number of cooling chambers and the fact that the chambers are emptied each time before the admission of fresh coke.

THE HELLER-BAMAG SYSTEM.

The author inspected at the gas-works, Potsdam, a system of cooling coke known as the "Heller-Bamag." Fig. 8 gives a view of the plant. This is not strictly a dry process, but the method is capable of yielding a very dry coke, and at the same time utilizes the heat of the incandescent coke.

The chamber for the cooling of the coke consists of a cylindrical vessel about 12 ft. long and 7 ft. 2 in. internal diameter, constructed of steel plates 30 mm. (1·18 in.) thick. One end of the vessel is closed by a very ingeniously contrived door. A wagon containing about 24 cwt. of hot coke is brought on rails to a position in line with the cylinder. The door is opened and the body of the wagon is pushed off its carriage into the vessel. The door is then closed and the coke is sprayed with water previously heated to a temperature exceeding 260° Fahr. Steam is thus produced, and also a small quantity of water gas, by the reaction of the hot coke and steam, causing the pressure in the vessel to rise quickly. The mixture of steam and water gas passes from the vessel to the tubes of a steam boiler. From the boiler the gases and vapours, deprived of much of their heat, go forward to a counterflow water heater. Here the steam is condensed; and the uncondensed gases escape through a relief valve and are conveyed to be mixed with the coal gas. The water heated in the counterflow heater is used for the spraying of the coke and also as feed water for the boiler. When the pressure in the cooling vessel commences to fall, the operator stops the supply of water to the spray; and when the gauge shows that the evolution of steam has ceased, the pressure is liberated and the door is opened. As the coke is still at a temperature of about 360° Fahr., it is claimed that, provided excess of water has not been used, the water in the coke will evaporate, cooling the coke still further and leaving it practically dry. The apparatus has been used with pressures rising to 14 atmospheres, but it is not considered advisable with the existing vessel to allow a pressure exceeding 10 atmospheres. The operation of cooling one wagon of coke occupies 15 to 20 minutes. At the time of the author's visit, the quantity of coke being produced on the gas-works was only sufficient to occupy the plant a small part of the day. At the commencement of operations the plant was cool; but after one wagon had been dealt with, the spraying water rose to 129° C. (232° Fahr.), and with subsequent operations it was a few degrees higher. The gases produced could be lighted by a match, and burned with a blue flame. The author did not take a

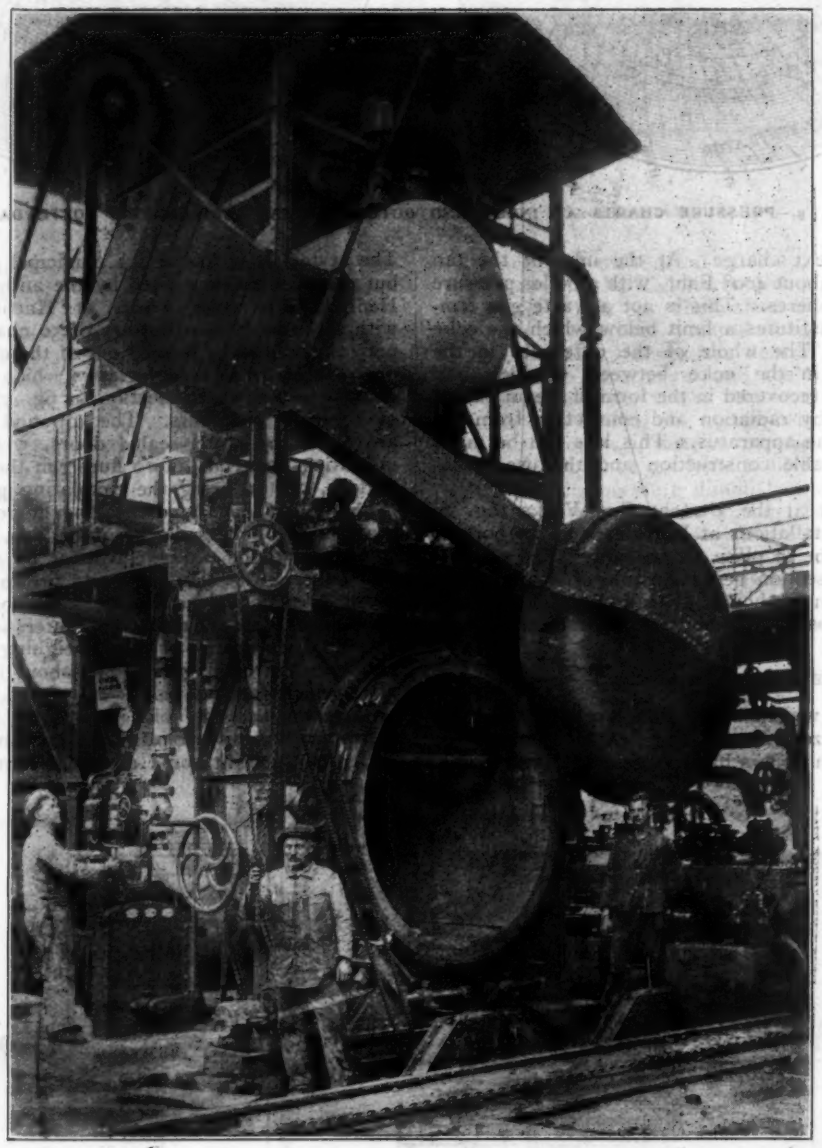

FIG. 8.—HELLER-BAMAG PLANT.

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sample of the gas, but he has been provided by the Bamag-Meguin Company with the following analysis and record of results.

CO_2	12·8 p.ct.
H_2S	3·2 ,,
O_2	0·0 ,,
CO	17·7 ,,
H_2	64·0 ,,
CH_4	1·3 ,,
N_2	1·0 ,,

This gives a C.V. of 2616 calories per cub.m. (295 B.Th.U. per c.ft.). With coke at 1000° C. it is claimed that about 50 cub.m. (1715 c.ft.) of this gas are produced per ton of coke and 300 kilograms of steam at 6 atmospheres. In addition a claim is made for the reduction of the sulphur in the coke. According to the above figures this latter would amount to 0·22 p.ct. on the coke.

The construction and working of the door of the cooling vessel is interesting. The door and mouth of the vessel have intermittent screw threads; the threads and spaces being about 1 ft. in length. The door is suspended by its centre on a counterbalanced arm attached to an overhead shaft. This shaft can be rotated and also moved longitudinally. To close the door the shaft is rotated until the door is opposite the mouth of the vessel. A longitudinal movement of the shaft brings the door close up, so that the screw threads are in position to engage one another. The same movement causes a projection on the door to engage with an arrangement by which a slight turn is given to screw the door firmly to its place, and make it steam tight. The whole of these operations are performed electrically.

Chemical Reactions.

The chemical reactions involved in these processes may now be considered.

In the Heller-Bamag system we have simply the reaction between water or steam and hot coke, producing hydrogen, carbon monoxide, carbon dioxide, and sulphuretted hydrogen. This is similar to what occurs when hot coke is quenched by water in the usual way, except that in the presence of air the sulphuretted hydrogen is oxidized and acids are formed which attack the neighbouring ironwork. The tubes of the boiler and superheater and the connecting pipes of the Heller-Bamag plant are of a special bronze; and it is claimed that no corrosion takes place because oxygen is absent. In the cooling vessel the temperature is sufficiently high to prevent the condensation of moisture.

In the Collin and Sulzer processes the circulating gases are derived in the first place from the air; a small combustion of coke quickly converting the oxygen to oxides of carbon. One pound of carbon in burning to carbon dioxide uses up the oxygen in 365 c.ft. of air.

When coke is withdrawn from the cooling chamber an equal volume of air must take its place. It is not difficult to calculate the effect of this air, on the supposition that the whole of the oxygen combines with the carbon of the coke to form carbon dioxide. Take 1 ton of coke as occupying 85 c.ft. 85 c.ft. of air contain 17·68 c.ft. of oxygen, which weigh 1·48 lbs. This is capable of combining with 0·55 lb. of carbon, which is only 0·024 p.ct. on the coke.

Attempts have been made to estimate the quantity of air which enters the Sulzer plant to balance the contraction due to the fall in temperature between succeeding charges of hot coke. Though the gases leaving the coke container vary by 200° to 300° Fahr., the temperature at the fan varies very little. The average variation throughout the plant will not exceed 135° Fahr. (75° C.). If the contraction due to this fall in temperature is made up by air leaking in from outside, this would amount on the Keilehaven plant to about 150 cub.m. per day corrected to 0° C. This quantity of air contains oxygen capable of burning 20 kilos of carbon, which is only 0·01 p.ct. of the 175 tonnes dealt with.

The supposition that the oxygen is entirely used to burn the carbon of the coke is, however, incorrect. There is always a certain quantity of volatile matter, chiefly hydrogen, given off by the coke, especially if, as happens at times, small quantities of coke are incompletely carbonized.

In the Sulzer plant provision is now made for the regular admission of air, if required, in order to burn the hydrogen, which otherwise might conceivably accumulate to an extent which is inadvisable. Table I. gives the average of a number of analyses of the circulating gases. Columns I. and II. each give the average of a large number of analyses extending over two months in two different plants at the Keilehaven Works at Rotterdam. Column III. gives the average of a number of samples taken by the author at the Utrecht Gas-Works.

Table I.

—	I.	II.	III.
CO_2	11·7	13·6	15·6
O_2	0·6	1·5	2·6
CO	4·3	2·2	1·7
H_2	5·2	2·3	1·9
CH_4			0·2
N_2	78·2	80·4	78·0
	100·0	100·0	100·0

The gases contain no H_2S; but a few determinations of the SO_2 show about 2·2 grammes per cub.m. This is equal to 0·15 p.ct. by volume, and would be included in the analyses as CO_2. These analyses take no account of the water vapour, which varies between 5 p.ct. and 15 p.ct. by volume on the dry gas.

The maximum percentage of hydrogen found by the author at Utrecht was 8·0, but higher figures have been obtained at Rotterdam before the systematic introduction of air.

The proportion of air purposely admitted is adjusted so as to keep the combustible gases in small compass. On the author's last visit to Rotterdam, the amount of air was measured very carefully. In one plant the average rate of admission was 172 cub.m. per hour corrected to 0° C. Only two 8-hour shifts are worked, and the fans work 19½ hours per day. On the basis of these figures, the quantity of carbon which could be burnt to CO_2 by the air so admitted is 370 kilos per day, out of 175,000 kilos of coke. Remembering that the hydrogen present uses up a considerable part of the oxygen, it is evident that there is no appreciable combustion of the coke.

Utilization of Heat.

It has long been known that the specific heat of carbon rises rapidly with increase of temperature. The following formulæ have been deduced by Debrunner from numerous experiments with graphitic carbon.

$$ct = 0{\cdot}517 + 7{\cdot}8086 \times 10^{-4}\, t - 6{\cdot}5724 \times 10^{-7}\, t^2 + 2{\cdot}384 \times 10^{-11}\, t^3 + 14{\cdot}425 \times 10^{-14}\, t^4$$

$$cm^t{}_0 = 0{\cdot}517 + 3{\cdot}9043 \times 10^{-4}\, t - 2{\cdot}1908 \times 10^{-7}\, t^2 + 0{\cdot}596 \times 10^{-11}\, t^3 + 2{\cdot}885 \times 10^{-14}\, t^4$$

To obtain correct figures for coke, account must be taken of the ash content. In accordance with the suggestion of Terres and Schaller, the specific heat of the ash may be taken as approximately that of silica. The presence of volatile matter tends to increase the specific heat, but with high-temperature carbonization the proportion is usually too small to need attention. Table II. shows

Table II.

Temperature, t °C.	Graphite Carbon. Specific Heat at t °C.	Graphite Carbon. Mean Specific Heat. 0 °C. to t °C.	Graphite Carbon. Heat Content per Gramme. 0 °C. to t °C.	Coke with 15 P.Ct. Ash. Heat Content 20° C. to t °C. per Gramme.
20	0·167	0·159	3·2	..
100	0·223	0·188	18·8	15·4
200	0·282	0·221	44·2	40·1
300	0·329	0·249	74·7	69·5
400	0·364	0·274	109·6	103·4
500	0·390	0·295	147·5	139·3
600	0·407	0·312	187·2	177·3
700	0·419	0·326	228·2	216·4
800	0·427	0·339	271·2	256·0
900	0·434	0·349	314·1	296·7
1000	0·443	0·358	358·0	338·3
1100	0·458	0·366	402·6	381·4
1200	0·483	0·375	450·0	422·0

how greatly the heat content of coke increases with the temperature, and the consequent possibility of usefully recovering it.

Careful tests have been made with the Sulzer plant at the Keilehaven Works. With coke at 1100° C., 466 kilos of steam per tonne of coke were produced at a pressure of 9·8 atmospheres absolute, from feed water at 57° C. Calorimetric observations of the coke taken before

and after cooling showed a difference in heat content of 352 calories per kilo. To produce 466 kilos of steam under the conditions named requires 283,924 calories, which indicates an efficiency of 80·6 p.ct. This determination was made before the systematic admission of air was introduced. Any air admitted undoubtedly affects the amount of heat available.

The air replacing the 175 tons of coke when withdrawn amounts to about 360 cub.m. per day. That entering to equalize the pressure on cooling is a possible 150 cub.m. Adding the air purposely admitted (3354 cub.m.) we have a total of 3864 cub.m. or 22 cub.m. per ton of coke. This is capable of producing 19,833 calories, which would increase the apparent percentage efficiency by 5·7.

The above calculation is made on the assumption that the whole of the oxygen combines with the carbon, and would imply the combustion of 0·23 p.ct. of the coke. If the oxygen is assumed to combine with the hydrogen of the volatile matter, the effect in heat produced is the same, but the reduction of weight is only one-third.

The power required to drive the fan is about 25 H.P., which reduces the quantity of steam available for other purposes by about 4½ p.ct. This, however, more than suffices for all the requirements of the gas-works, leaving a surplus of electrical energy to be supplied to the Electricity Department of the Municipality.

VALUE OF DRY COKE.

The greater efficiency of a fuel free from moisture is becoming more and more appreciated. If a coke contains 10 p.ct. of water, this water has to be evaporated before it can be ignited. The coke is thus not only inferior because of the smaller percentage of carbon, but heat is absorbed in evaporating the water, and raising the vapour to the temperature of the waste gases.

For instance, if the coke is used to heat retorts and the products leave the regenerator at 600° Fahr., we obtain the following calculated results per kilo of coke containing 15 p.ct. of ash on the dry sample.

—	Dry Coke.	Wet Coke.
Carbon	85 p.ct.	76 5 p.ct.
Ash	15 ,,	13 5 ,,
Water	..	10·0 ,,
Heat of combustion of carbon	6868	6181
Less to evaporate water from 60° Fahr.	..	62
,, to raise vapour to 600° Fahr.	..	16
Available heat	6868	6103

This shows a depreciation of 11 p.ct. due to the presence of the water.

CONCLUSION.

The dry cooling of coke has, therefore, the following advantages.

(1) Higher calorific value of the coke.
(2) Smaller percentage of breeze. The author has not attempted to put a figure on this, as it depends so greatly on the coal being carbonized.
(3) The saving in the water required for quenching is sometimes important.
(4) The production of steam by the Sulzer process is equivalent to an increase of 6 p.ct. in the coke available for sale.

The author desires to express his indebtedness to Mr. M. C. Sissingh and Mr. P. H. Hendriks, Directors of the Rotterdam Gas-Works, who, with their staff, have given him much information and assistance; and also to the various firms and managers of works in Holland and Germany for many facilities provided.

Discussion.

The PRESIDENT: It seems to me that the two most important points involved in this paper are, first, the economy of heat used in the carbonizing process, and, secondly, the important one of the so-called dry quenched coke. I am not sure what the reasons are which have prevented Mr. Leather from giving us any financial figures. It may be that the economy of heat used in the carbonizing process is obtained at too high a cost from the point of view of actual financial efficiency. Probably some of the speakers in the discussion may raise this point. As has been implied right through this meeting, too much cannot possibly be said with regard to the importance of dry coke; and it does seem to me that this is really the most important matter contained in Mr. Leather's paper. I am hopeful that we shall have a good discussion, especially upon this particular point.

Mr. G. M. GILL (London): Like the other members present, I have been very interested in this question. I have seen the plant at Keilehaven on two occasions; and there is no doubt that there is a great deal in this question of dry coke cooling. Mr. Leather speaks of the "Dryco" system. Some little time ago I was concerned with the building of a horizontal retort installation at the Fuel Research Station, and there it was desired to produce a coke containing no water, for obvious reasons; and finally we adopted the "Dryco" system. It certainly answered the purpose, though I do not think it can be equally highly efficient. It produced a large quantity of lukewarm water, and it took some considerable time to cool the coke sufficiently to discharge it without quenching with water. However, it justified its adoption. It seems to me that with these other systems, such as oven systems, to compete with vertical retorts, in which the coke is cooled by steam in a very efficient manner, they will have to use the heat in the coke to produce steam; and I should say that they are more likely to adopt some method of dry cooling than are retort systems. I remember that in Mr. Hardie's Presidential Address before the Southern District Association he mentioned some figures of the Bow Common installation of Woodall-Duckham verticals, and I worked out that the figures, anticipated from the guaranteed results, would give a fuel consumption of something like 5 p.ct.—*i.e.*, if you gave credit for the amount of steam raised in the waste-heat boilers. That is something for other systems to compete with. Mr. Leather makes a point at the end of his paper that there is a smaller percentage of breeze in this system; but I rather doubt it, because the coke has to be tipped into this cooling vessel, and at the bottom it has to be dropped out again into wagons or conveyors or whatever you may use. This handling I should say makes breeze, which you have got to place against the advantages. In fact, at the Rotterdam Works there was one part of the process which seemed to me an awful nuisance. There was a lot of very fine coke dust all over the works. I took away an appreciable quantity down my neck and in my shoes. It was a very dry and fine dust, and I made the suggestion while I was there that if I were in charge I should put a little water on the coke, to prevent this dust. I feel confident with Mr. Leather that these dry coke cooling systems are bound to come. Whether it will be the Sulzer system or some other is a matter of opinion.

Dr. E. W. SMITH: I have nothing at all new to say on this subject. Everyone knows how strongly I feel about the necessity for dry coke. In going about the country at the request of various people, and investigating the subject of coke sales, one is tremendously impressed with the enormous differences between the troubles that occur in works where coke is definitely treated seriously, and in works where coke is only treated seriously when there are big stocks. While I cannot add anything technical to the subject—there is any amount of information available in the Press on the Sulzer and other systems and processes as to the question of thermal efficiency—one cannot but continue to stress this subject of the importance of dry coke. I am particularly afraid that the problem may tend to be dropped, and that it will not loom as important six months hence as it did (say) six months ago; but the only way in which there can be any serious progress in the gas industry is to treat really seriously every product made by the carbonization of coal.

Mr. E. G. STEWART (Gas Light and Coke Company): One interesting point from Mr. Leather's paper is that the amount of steam raised by this drying process is of the order of 600 lbs. per ton of coal, according to the author's figures of 460 kilos per ton of coke. I am assuming 12 cwt. to the ton; and that means roughly 600 lbs. of steam per ton of coal. This, Mr. Leather says, suffices for all the requirements of the gas-works. I think it is an extraordinarily low figure for power on a gas-works. It should be twice as great. I would like to ask Mr. Leather if what I am going to suggest has happened at Kielehaven—*i.e.*, the steam is used on the works to generate electricity, the electricity is sold to the municipalities, and the works buy back from the municipalities as much current as they like.

Mr. RALPH E. GIBSON (Liverpool): I think we are all very much indebted to Mr. Leather for bringing this matter forward. It is a very timely paper. Most of us, if not all of us, are agreed as to the desirability of producing dry coke. In Liverpool recently we made some tests with regard to burning coke in an open grate. We tested all our various cokes; and they gave very different results. One coke ignited freely and burned rapidly; another coke was difficult to ignite, but lasted a long time. It seems to me there are conditions under which slow-burning coke is required and is desirable. Domestic coke boilers, which do not need to be lighted every day, but burn throughout the 24 hours, for instance, might very well be fed with a slow-burning coke. I mention this because possibly we might go too far in this direction of dry cooling, and it might not be worth while in some cases. Refer-

ence has been made to dry cooling at Liverpool. We made a modest attempt there to produce dry coke at a reasonable cost, but it seems to me that the Sulzer is a very costly plant to instal. The dry cooling chambers we have at Garston have been in continuous use since they were put up in 1922, with the exception of a period when they were under repair, and possibly a time when the bench was out of action for repair; but we are thoroughly satisfied with the results. The coke produced is of excellent quality, and we obtain the benefit of it in our water gas plant and in domestic sales. The whole of our domestic sales at Garston are effected from the dry coke stocks.

Dr. PARKER (Leeds University): I wish to refer again to the point already raised by Mr. Stewart. I have made calculations on this subject of steam raising by coke cooling on many occasions before, and I remember the guarantees given by the Sulzer people for various processes—guarantees which can be easily fulfilled as far as one can calculate. I know, however, as Mr. Stewart has noted, that the amount of steam raised in the tests mentioned in the paper is roughly 700 lbs. per ton of coal carbonized, assuming about 14 cwt. of coke per ton of coal. A quantity of 700 lbs. per ton of coal carbonized appears to me to be a low figure for the power required. It is, as far as I can gather—and I have been making a good many inquiries into this subject recently—roughly only half the steam used at present in gas-works in this country. So that one cannot expect it to produce all the auxiliary power, even if this amount of steam were raised here. I note that the temperature of the coke in these tests at Keilehaven was 1100° C., but I would like to ask whether Mr. Leather thinks I am correct in assuming that with horizontal retort practice here one must take the average temperature of the coke as nearer 900° C., rather than 1100° C. This would cut down the amount of steam which can be raised per ton of coal carbonized to about 500 lbs. I mention this figure because I recently made calculations without taking these test figures, and I came to the conclusion that in horizontal practice here we should be able to raise from 400 to 500 lbs. of steam per ton of coal carbonized.

Mr. J. W. MCLUSKY (Glasgow): This question came up in connection with our new plant at Dawsholm. We had either to use our waste-heat boiler or to put in an installation of new boilers, so that, by coming to a decision with regard to the Sulzer plant, we had it in our minds that we were going to avoid putting in a new installation of boilers. When we saw the plant in Rotterdam we certainly decided that the fuel was very dry. The dust was blowing all over the place. There was a breeze, and the men were wearing goggles and special overalls. A little Jeffrey loader was used for putting the dust into wagons, but only some of it got into the wagons. The rest settled over the works. Some of you sell water in your coke, and pay 1d. a gallon for it. There is no reason why a little of this water should not be used judiciously to avoid this dust nuisance. We suggested in Keilehaven that atomized water might do; and they agreed that they were thinking about something of this nature. Certainly the dust was a great nuisance, but they were getting special customers and very favourable contracts for this special coke. I found, in connection with a chain of coke ovens around Essen, which carbonized about as much coal as the whole of the British Isles, that the metallurgists will not pay for more than 4 p.ct. of moisture. I do not know that there are many people here to-day selling coke who are tied down to 4 p.ct. of moisture. The best we can do at Provan with coke, which looks as nice as any produced, from about 40 coals, is 8 p.ct. of moisture. If we are to secure favourable contracts and give guarantees, then we must keep the moisture content down to the lowest possible figure. We can guarantee the size of coke—clean coke, containing almost 90 p.ct. of fixed carbon—however. I wish Mr. Leather had told us that he recommended this system to the Burnley Corporation. He is so modest that he does not even say in his paper that he has recommended it; but I think it is right that Burnley intend to put it in. Is not that so?

Mr. LEATHER: Yes.

Mr. MCLUSKY: We installed it, and the cost was £18,000. It sounds a lot at first, but it has to deal with 25,000 tons of coke per annum, and it will certainly give us a credit to the extent of £4000 per annum. As we are all anxious to prove to coke buyers that we want to improve their market, this seems to be the correct line to follow. People who are interested in fuel research and heat conservation marvel at the idea of huge fires being extinguished in Glasgow, only to find round one corner other fires heating firebrick work, and round another corner other fires raising steam. It does seem a pity from the heat expert's point of view; and if we can conserve heat, and turn it into some other form of power, it is surely worth while doing. It is mentioned that they had an arrangement on the Continent for selling to the electricity department; and that is true. They are in a unique position; and it might be that a gas undertaking can adopt a scheme whereby surplus steam or surplus power could be sold. Companies and corporations have been known to do this. In Blackburn we bought steam from the destructor plant; and these things have been done, and can be done again. I hope Mr. Leather will tell us something about the financial side, because I am rather anxious to compare the Burnley figures from the point of view of the amount of coke treated and the financial credits arising from the installation of such a scheme. I am thankful to Mr. Leather for the information he has given us. If we are to meet the dust problem in breeze, it might be done in the manner suggested. As a man said to me in Essen, if an expert buying fuel is satisfied with a coke containing 4 p.ct. of moisture, why not give him such a coke. This was a German expert who has been ten years in England. It may be that 4 p.ct. of moisture will eliminate the dust nuisance.

Mr. F. P. TARRATT (Newcastle-on-Tyne): About six months ago I had the opportunity of seeing the Sulzer plant at Rotterdam; and though I would not like to do any harm to the introduction or use of this plant, I must confess that I was not at all impressed by it, mainly for the reasons mentioned by other speakers. First of all, the cost seemed to be prohibitive. Further, the dust nuisance on the works was appalling. I have never seen anything like it in my life. You talk about the dust in a retort house; but what I saw at Rotterdam beats the worst I have ever seen here. There was no wind on the day I was there, but we walked in a cloud of dust. They would not attempt to put water on it, and there were undoubted signs of the coke being burned. I examined a good many of the trucks, and saw a train of coke being taken out. There was more spoiled coke in that train than I have ever seen in my works in twelve months. This, however, might be due to faulty handling of the plant; but I must say I was not favourably impressed, though I appreciate as much as anybody the necessity for dry coke.

Mr. J. H. CLEGG (Burnley): It has been rather interesting to me to listen to what may be termed the view of the man in the street. We have heard the experience of Mr. Leather, who has evidently spent some time studying the problem of coke cooling by three different systems, and some of the remarks we have heard since are rather amusing. It is true that there is a certain amount of coke breeze produced in the handling of this Sulzer plant, and that when the coke is extracted from the cooler there is a large amount of dust flying about. It has not, however, been mentioned that it is only on very rare occasions that the container is opened, so that the amount of dust that comes out from it is negligible. The first plant at Keilehaven was an adaptation of existing plant, and the conditions under which they worked there were the very worst. They had frequent cracks in the concrete construction, which are not taking place in the newer structures; and this would account for the partially burned coke. In the case of the plant to be erected at Burnley, the cooling chamber will be constructed of steel, in order to avoid such possible occurrences. Also the method of extraction of the coke has been improved, so that there is not the amount of friction in the coke which they had formerly, and the coke as it is removed from the container is in an entirely closed vessel, and will be deposited gently and quietly into the bulk elevator.

Mr. McLusky issued a kind of challenge to compare figures with Glasgow. I do not intend to be drawn into any discussion on the financial side. After Mr. Leather recommended the plant to the Burnley Corporation in 1923, some time elapsed before we proceeded with the question. I think it was in 1924 that I inspected the plant in Holland, and it was last year that we gave the order, after careful consideration. The extent to which I intend to go is to say that we expect the installation to be a commercial proposition. I do not expect all the results in steam production which are claimed by the makers, nor even to approach the figures stated by Mr. Leather. Dr. Parker hit upon a very important point. The bulk of the practice in Holland appears to be carbonization by coke ovens; and there you have large quantities of coke discharged. At Utrecht 6 tons of coke per charge is drawn from each oven, and this quantity is sufficient to fill one truck, which is conveyed direct to the cooler. They also work at much higher temperatures than we do in ordinary practice in horizontal carbonization. We are up against the difficulty of discharging coke from retorts, which, even when filled, will not give more than 12½ cwt. per ton, and we intend to clear the coke from these retorts until we accumulate three tons. A certain amount of cooling takes place until the truck arrives at the container, but for any English gas engineer to anticipate a temperature anywhere approaching 1100° C. is, of course, out of the question. From tests which I have made on our present works I expect to get a temperature of about 850° to 900°; but even then I fully anticipate the project will be a paying one. As Mr. McLusky has pointed out, there is the saving in capital expenditure on your boilers. There are advantages which Mr. Leather has mentioned, and there is another advantage which he has not mentioned, and which cannot be calculated in terms of £ s. d., and that is the absence of acid-laden fumes and steam in the works. The saving in corrosion is undoubtedly a big item in connection with the coke handling plant in the retort house.

To proceed with the point of view of coke handling in general, the Heller-Bamag plant is an interesting one, but I do not view with any favour the addition of steam in the process of cooling. I think one of the objects of dry coke cooling is spoiled in that way, and I think you detract from the appearance of the coke. I certainly agree that the removal of sulphur is in some cases an important point, and I am interested to

note that no sulphurous acid fumes are produced which would tend to the corrosion of the funnels. This is rather difficult for me to believe; and I wonder why the makers of the plant should be so pessimistic as to put in bronze tubes. There is no doubt about it that attention should be paid to the production of a coke suitable for all purposes. I noticed a remark in Mr. Gill's paper this morning—if I may refer to it now—about the ease with which we can get rid of our coke, provided we have the selling ability. I wish this were so. I think we have a long way to go yet before we can get the required market for the whole of our supplies of coke; and it is up to us to try to produce a coke suitable for all purposes, free from moisture, and with a good ignition point. The fact of having a dry coke gives us all the advantages of a vertical coke with the full advantages of horizontal coke, which I am sure are appreciated by many coke consumers. The vertical coke, even when it is dry, is not popular in all towns. Burnley may be an exception, but the people of Burnley will not buy vertical retort coke. They find that it does not ignite so readily as coke from the inclined retorts; and they tell us frankly that we have taken too much out of it.

The PRESIDENT: Personally I hoped that we should have drawn much more information from the financial point of view. We got a little from Mr. McLusky, but he referred purely to the cost of installation, and not to actual maintenance costs. I think, however, the discussion has made two points clear. The first is undoubtedly that there is dust trouble, and the second is that our Scotch colleagues apparently are willing to retain all their national beverage for home consumption, and, at the same time, are willing to sell water at 1d. per gallon to quench their dust!

Mr. LEATHER, replying to the discussion, said: I am glad the discussion has taken place, though there may be some questions asked which I do not feel I am in a position to answer. I have not said anything about the question of financial considerations which the President introduced, and to which others have referred, because as far as possible I wanted to keep to what I actually knew from my own experience. Wherever in the paper I have quoted something that I have not verified, I say the makers claim so and so; but I have verified by experiment a good portion of the figures I have given. Even though some of the figures are those taken by other people, I have found similar results in my tests. When, however, it comes to the question of financial considerations, it is a matter, so far as I am concerned, of estimation. I certainly estimated that there would be a considerable gain from the adoption of the plant before I recommended it to the Burnley Corporation. Mr. McLusky has told us that he has estimated an advantage of £4000 per annum from his expenditure of £18,000 or £20,000. These are estimates. All we can say is that, as regards actual practice, the gas-works on the Continent have adopted the system, and have increased their use of it. At any rate this applies to the Rotterdam Corporation. They had a plant a number of years ago; and as the result of their experience, I suppose, they have increased that plant considerably. That is about all I can say on the financial side. Mr. Gill questioned the advantage as regards breeze, because of the way in which the coke gets a certain amount of handling in the Sulzer process. The Rotterdam people—I can verify this from my own knowledge—say that they have less breeze than they used to have. With regard to dust, there is a certain amount of this; but I should not like to use language such as Mr. Tarratt used, and say it is more than one has ever seen anywhere else. When the coke is raised over the top of the cooling plant, and is discharged, a certain amount of dust flies about in the immediate neighbourhood, but I do not think it is sufficient to condemn the plant from the financial point of view. It is not a great amount.

Dr. Parker thought I had over-estimated the value of the steam in saying that the process produced steam sufficient for all that is required on the works. At Utrecht the gas-works there produce steam sufficient to generate all the electricity required, to supply the producer plant—their ovens are heated by producer gas—and to work their sulphate of ammonia plant; and they have a surplus. Perhaps there may be special circumstances in connection with Utrecht. As a matter of fact, I have investigated that plant closely, and I think they are probably midway at any rate. I do not know whether the plant has been altered, but at the time I was there I think they were admitting more air—there were some faults which have since been remedied—than was really necessary. Consequently they might have been producing a little extra steam very much in the same way as many gas-works make more steam from waste heat than they ought to have waste heat on the works. This may possibly account for Utrecht; but at Rotterdam, where the plant is working exceedingly well, and is in good condition, I think they are producing all the steam needed for the works. There is some talk of supplying the municipalities, but I do not think they supply very much to the municipalities there. When I was calculating the quantity of steam required for a new works to be erected at Burnley, I came to the conclusion that the quantity of steam from the Sulzer plant was nearly enough; but I did not take into account the higher claims of the makers. Taking, however, what they were prepared to guarantee, there was nearly enough steam to produce all the power required on the works, apart from the C.W.G. plant, which would produce its own power. In addition, I recommended—and they are being put in—the use of the waste-heat boilers on the retort benches. I consider that the Sulzer plant and waste-heat boilers on the retort benches would, at any rate together, provide more steam than is required on the works for all purposes.

One or two interesting remarks have been made by other gentlemen but not very much that calls for reply, except perhaps those of Mr. Gibson, who spoke about the question of whether you really need coke that ignites easily. My own experience is that coke in a domestic heating apparatus does not burn continuously in an economical household. Perhaps I cannot afford to keep my heating apparatus going 24 hours a day all through the year. Therefore it is a good thing to have a coke which ignites easily when the fire has to be lighted. Certainly I do not think there is any disadvantage in such a coke. I was glad that Mr. McLusky confessed to 8 p.ct. of moisture in his coke, because I have known some gentlemen—I do not think they have tested it very carefully—claim that their coke contained much less than that amount. In a discussion last year or the year before, someone thought it out of the question that his coke was not practically dry.

REPORT OF THE REFRACTORY MATERIALS JOINT COMMITTEE.

The Joint Committee of the Institution and the Society of British Gas Industries appointed for the year 1926-27 consisted of Mr. J. P. Leather (Chairman), Dr. J. W. Mellor (Director of Research), Messrs. J. Ferguson Bell, C. F. Botley, Prof. John W. Cobb, Dr. H. G. Colman, Messrs. T. Hardie, W. H. Johns, P. N. Langford, H. D. Madden, W. E. Price, T. F. E. Rhead, Dr. E. W. Smith, Messrs. S. Tagg and J. Wilkinson (representing the Institution); and Messrs. T. Allen, M. Barrett, F. H. Brooke, Albert Cliff, G. V. Evers, J. W. Fagan, W. T. Gardner, G. H. Pearson Perry, and Frank West (representing the Society).

The recent regretted death of Mr. Albert Cliff has removed a member who took an active interest in the work of the Committee from its inception, and whose co-operation as a manufacturer was highly appreciated.

As foreshadowed in last year's report, the Committee have again considered the clauses in the Standard Specification dealing with the test for the after-expansion of silica material. Several proposed alterations claimed attention, including the incorporation of a test for specific gravity. It was, however, agreed that, in the present state of our knowledge, it was not advisable to make any change. The British Refractories Research Association has been asked to institute a series of tests on a considerable number of silica bricks of as large a variety as possible; the information at our disposal being too restricted in character for an important decision to be based upon it. The Research Association has also been requested to report on the present position of knowledge relating to materials suitable for the insulation of retort benches.

The Association has continued its researches during the year, though want of funds has compelled some reduction in the staff. In accordance with a suggestion made at the Institution meeting last year, the usual detailed reports of these researches are not appended to this report. In lieu thereof, Dr. Mellor has asked members of his staff to prepare summaries of the work done on problems connected with the gas industry. Reports are accordingly presented herewith with the permission of the Association by Mr. A. E. J. Vickers and Mr. A. J. Dale under the following titles:

(A) Effects of Furnace Atmosphere upon Refractory Materials.
(B) Sillimanite Refractories.
(C) Load Bearing Capacity of Siliceous Products at High Temperatures.
(D) Some Properties of Quartz-Clay Mixtures.
(E) Effects of Firing Temperature, Grog Kind, and Grading on the Properties of Firebrick Material.
(F) Some Experiences of the Behaviour of Silica Retorts, with Special Reference to Slag Formation and Corrosion.
(G) Other Researches on the Manufacture and Properties of Refractory Materials.

[These reports, and the discussion, together with Mr. Leather's introduction, will be published next week.]

SOME EXPERIENCES OF GAS SERVICE.

By J. H. CANNING, O.B.E., F.C.S., of Newport (Mon.).

During recent years the number of papers and communications relating to gas service has progressively increased, and as late as last year included two very able and comprehensive contributions to the proceedings of this Institution. The only apology, therefore, which can be offered for the appearance of the present paper is the importance of the subject and the interest which is at present felt in regard to it.

The terms and conditions upon which such service is rendered in various districts have already been dealt with so fully and exhaustively that it would be quite superfluous to endeavour to add to the valuable store of information of this kind which is already available. In many cases, however, the readers of papers have dealt with methods which, while admirably adapted to the conditions obtaining in gas undertakings of the largest size, are not always applicable in those of more modest dimensions. It is proposed, therefore, in the present communication to deal with general principles rather than details, with experiences and results rather than routine, and to give a candid statement of both success and failure in the endeavour to carry into effect the principles of gas service in an undertaking of moderate size.

In the early days of the gas industry, it was generally considered sufficient to provide a supply of gas, and to leave the consumer more or less to his own devices in respect of the proper utilization thereof. Consequently, very little reference is made in the earlier treatises on gas manufacture and supply to anything beyond the actual production of gas, its distribution through mains and services, and its accurate measurement. There occurs, however, in Peckston's "Practical Treatise on Gas Lighting" a passage pointing out the great importance of the proper arrangement of gas fittings, the proportioning of pipes, and good workmanship, which concludes with the following words:

> "For want of such precaution, mistakes have arisen injurious to the consumer and detrimental to the interests of the gas manufacturer; the former being annoyed by escapes of gas, or by some of his lights burning indifferently, speaks of the circumstance to his neighbours, and thus prevents them from using gas, so that thereby the manufacturer of that article loses the profits upon a portion of gas which would otherwise be supplied."

It may be claimed that this short extract contains the germ of the modern idea of gas service, which has as its object the benefit of consumer and undertaking alike, and recognizes that the surest method of safeguarding the interests of a supplier of gas is reasonable consideration of the interests of the consumer. It is to be feared, however, that the monopoly which gas then enjoyed prevented the importance of this great principle being fully realized. It must, however, in justice to our predecessors, be stated that a stern sense of duty to the undertakings they controlled had its influence in inducing them to terminate their responsibility, as far as possible, at the consumer's meter. Insurance companies were not prepared at that period to issue policies for third-party risks; and there was consequently a tendency to limit responsibility. To such an extent was this principle carried, that some undertakings were reluctant for a long time to employ a fitting staff, with its attendant liabilities. With the advent of electrical competition, however, and the arrival of an era in which mankind generally has become more critical and more exacting, gas undertakings, in common with many other public services, have been obliged to reconsider their position, so that to-day it is hardly a question of the expediency or otherwise of service, but rather the extent of its application and the best means of giving it effect.

Gas service in the widest sense embraces all the activities of a gas undertaking; for it necessarily connotes the supply of gas of adequate and uniform calorific value at a sufficient pressure, with the absence of considerable or sudden alterations in composition or specific gravity and freedom from interruption. To these requirements may be added the proviso that the flame temperature of the gas, when properly consumed, shall be sufficient to ensure the efficient working of apparatus for the production of radiant energy in the form of light or heat.

Service Pipes.

In order that the individual consumer may realize to the full the advantages attendant upon such a supply of gas, it is essential that his service pipe should be large enough to meet the full peak load of his demand without an excessive drop in pressure. Experience shows that a wrought-iron service pipe, laid in good soil, has a fairly long life; but it is questionable whether it is a real economy to permit such a pipe to reach the full term of its possible survival, if it be not fully adequate to meet the modern demand for gas for heating and cooking purposes. Similar remarks apply to services of undue length, which are also peculiarly liable—especially near the channelling of the roadway—to develop, as a result of the increased weight of motor traffic and steam rollers, dips in which condensed water collects. In very wide main thoroughfares, where expensive methods of road surfacing are now being adopted, the provision of auxiliary service mains under the footpaths—particularly on the side further distant from the existing main in the roadway—is well worth consideration, as the adoption of this course not only obviates future costly road reinstatement charges, but reduces the length of services very substantially.

It may be here mentioned incidentally that the authorities responsible for the construction and maintenance of roads appear never to have realized or acknowledged in any way the very great relief of traffic which has been afforded them by the gas industry during the immense development of gas for heating and cooking purposes. The widespread adoption of gas as a fuel has eliminated a vast amount of traffic, and has not only relieved highway congestion, but must have reduced considerably the cost of road repairs. This service should certainly be considered a very substantial contribution to the local rates.

The necessity for careful attention to consumers' services was strikingly manifest at the close of the recent war, when, as a result of the depletion of main and service laying staffs, owing to military requirements and the abolition of the Leaving Certificate, it was impossible to cope adequately with the maintenance and repair of gas services, and the accumulated arrears, until finally dealt with, proved a source of dissatisfaction. At Newport, since 1919, 3144 services have been re-laid; and, both as a result of experience and with a view to future development of gas sales, the diameter of service has been increased from ¾ in. to a minimum of 1 in. The provision of ample service facilities not only improves the supply to the consumer, but makes provision for other factors which have to be considered in present practice.

Water-Slide Chandeliers.

In the modern acceptation of the term, however, gas service is considered to refer more particularly to activities on the part of the gas undertaking over and beyond those which have been briefly outlined above. Prior to the introduction of the incandescent gas burner, the only activity of this kind was the renewal, free of charge, of flat-flame burners; but, about 35 years ago, a further extension of what may be termed service took place. About that period, a number of worn-out water-slide chandeliers and pendants were the cause of serious escapes, resulting occasionally in explosions; and it became necessary, in the interests of consumers, to locate these fittings and to issue a notice pointing out the danger of continuing to employ them. This work has been persevered in steadily until the present day, and a notice has been issued in every instance where fittings of this type have been discovered; but, in spite of the urgent representations which have

been made, this type of fitting has not even yet been entirely eliminated. In many cases consumers are reluctant, for sentimental and other reasons, to discard chandeliers of ornate pattern; while in other instances motives of economy stand in the way. The number of notices sent out in each of the last three years is as follows.

1924	62
1925	12
1926	9

Up to the present, two notices have been issued in the current year; and it is hoped that very shortly this type of fitting will have been finally relegated to the scrap heap. It may be added that each warning notice has been followed-up by an estimate offering upon the lowest possible terms to replace the undesirable fitting by a modern pendant yielding more efficient and more economical lighting.

Burner Maintenance System.

In 1898 a system of maintenance of incandescent burners was established, and has been in operation ever since. It has been generally assumed that this branch of gas service was established as a result of electrical competition. Competition was, no doubt, an influencing factor; but it must be remembered that in any circumstances it would have been necessary to establish some system of the kind, in view of the fact that incandescent gas lighting was an innovation, and that the gas mantles of those days required very delicate handling, while gas consumers generally were not competent to attend to their own incandescent burners. The price originally charged for this service was 2s. per burner per annum; and no variation has been made in this, although the increased cost of labour and mantles has rendered the work even less lucrative than it was in the commencement. In view of the subsequent development of burners with multiple nozzles, a charge of 2s. is now made per nozzle per annum, and includes, in addition to the replacement of mantles, regular cleaning and adjustment of burners, but not the replacement of glass, or repairs to burners and accessories.

In the absence of previous experience, some difficulties were encountered. It was discovered, after a short trial of the system, that certain consumers were receiving more careful attention than others; and investigation revealed that in every case these were individuals who, in accordance with immemorial British custom, were in the habit of bestowing gratuities, of one kind or another, upon those who rendered them service, however trivial. Experience has shown the futility of endeavouring to change the habits of the public in this respect; and steps were taken to ensure equality of treatment. The work done by maintenance men was more frequently inspected; while in every case where neglect had occurred, or was suspected, printed postcards were left with consumers, in order that they might, with the least possible trouble or inconvenience, notify the Company of any complaint. It has been possible to discontinue the postcards; but the inspection is, of course, maintained. Each consumer receives attention at least once a month; and where inattention is suspected, or complained of, a special visit of inspection is paid.

Another difficulty arose from the fact that consumers placed worn-out and defective burners under maintenance. In the commencement, the obvious course was taken of refusing to accept burners for maintenance unless they were in satisfactory condition; but it was soon discovered that this played directly into the hands of competitors. All burners in a workable condition are taken under maintenance; but a special canvasser has been appointed, furnished with a hawker's licence, who carries with him in a portable case samples of two or three kinds of thoroughly efficient burners, which are fixed free at moderate prices. The canvasser is always prepared to fix one of these in place of a defective burner, and to demonstrate to the consumer the advantages to be gained by the substitution of the improved type. This departure has proved successful; and in the year 1926 the canvasser in question disposed of 815 burners, and was undoubtedly instrumental in securing the continuance of gas lighting in many instances. The primary business of this salesman is to sell burners; but the increased sense of satisfaction among consumers brought about by his efforts has reacted in other directions, for in the same year he sold, in addition to the burners, the following:

Cookers	17
Grillers and hotplates	1
Boilers	17
Gas irons	9
Boiling rings	18
Fires	60
Radiators	4
Lamps	15
Fittings	397
Globes and shades	667
Mantles	1309

Two further advantages have been also secured. When any form of gas apparatus is out of order, the consumer invariably assumes that the cause of the trouble is gas of inferior quality, or a deficiency of pressure; and such a canvasser can do more by ocular demonstration to destroy such a fallacy than could be effected in any other way. It is also gratifying to find that his sales of burners and gas apparatus have shown a progressive increase since the appointment was first made; and his activities have resulted in a vast diminution in the sale by hawkers of the cheap and trashy burners which have done so much to discredit gas lighting.

Other Appliances.

Up to the present, no definite system of maintenance of gas fires, radiators, cookers, or boilers has been established; but, generally speaking, each case is treated independently. Prepayment and hired gas cookers receive, of course, free maintenance; but where a gas cooker is a consumer's own property, an estimate is furnished for whatever is required in the way of repairs or cleaning. Although cases are not wanting in which hired cookers have received exemplary care and attention from consumers, it must at the same time be admitted that where a consumer owns his own cooker, the apparatus receives, in practically every instance, more care and attention from the owner than is given by the average hirer.

Systematic Inspection of Fittings and Apparatus.

At the close of the war, defects and leakages in gas apparatus received a degree of public attention out of all proportion either to their extent or significance; and it was gratuitously assumed that conditions arising out of unexampled circumstances represented the normal state of affairs with regard to gas distribution and apparatus. The actual facts were, of course, that, as in the case of public roads and the permanent way of the railway companies, it had been impossible, owing to the lack of men and materials, to carry out adequate repairs and renewals.

It was obvious that exceptional circumstances demanded something in the nature of exceptional measures to meet them; and the Directors of the Newport (Mon.) Gas Company decided to adopt the policy of making a systematic inspection of consumers' fittings and apparatus. This work was entrusted to a gasfitter possessing both tact and experience, who carried out the work in an adequate manner. At each house he visited he presented a printed introductory card, of which the following is a copy:

> The Newport (Mon.) Gas Company is prepared, without accepting responsibility, to examine your gas fittings and appliances, and ADVISE you thereon FREE OF CHARGE.
>
> This card is to introduce the Gas Company's Inspector, to whom this work has been deputed; and if you will grant him the necessary facilities, he will be most pleased to place his services at your disposal.
>
> Communications with respect to this matter should be addressed to the Engineer and Manager, Newport (Mon.) Gas Co., Mill Street, Newport, Mon. Telephone No. 2257. Day and Night Service.

It may be added that the card is over-printed diagonally in red with the following:

PLEASE NOTE THAT THE INSPECTOR PRESENTING THIS CARD WILL WEAR THE COMPANY'S UNIFORM.

In explanation of this, it may be stated that an unauthorized person had, shortly before the inspection was commenced, by representing himself as an official of the Company, obtained money from consumers on false pretences, by securing advance payment for gas fittings and appliances which, it need hardly be added, he had no intention of supplying. Shortly after this period, as a

further precaution, all inspectors, canvassers, meter inspectors, and members of the fitting staff, were provided with identity cards with an attached photograph; and consumers are duly notified that they are entitled to ask any representative of the Company to produce his identity card.

DEFECTS DISCOVERED.

No attempt was made to carry out a detailed examination, as the object of the inspection was to locate, as rapidly as possible, escapes, fittings, and workmanship (very often amateur) which presented the possibility of danger. On an average, 210 consumers' premises were visited weekly, at a cost of approximately 5d. per visit; and in some 4½ p.ct. of the installations inspected, fittings or workmanship of potentially dangerous character were discovered. In addition, many escapes were found; but these were, as a rule, of a minor character, and could not be classed as dangerous. In most instances the dangerous condition of the fittings was the direct result of the use of the old type of brass tubing with brazed or soldered butt joints. In one case the down-tube of a pendant was actually found to be split for a length of some 20 in.; but the consumer had smeared the crack with soap, and was apparently quite prepared to put his trust indefinitely in this makeshift repair. A little knowledge is proverbially dangerous; and, in accordance with this well-worn adage, the most glaring cases of utter disregard of personal safety were brought about by the well-meaning efforts of amateur gasfitters. The following are examples:

(1) Split tubes, stopped with white lead.
(2) Escapes of varying magnitude stopped with soap.
(3) Open ends of pipes stopped with corks.
(4) Brackets found hanging on nosepieces without blocks.
(5) Pendant connected to ceiling-plate with rubber tubing.

In some instances, however, the efforts of amateurs were far more ambitious. One individual ran a supply to an outlying portion of his establishment with 40 ft. of ½-in. rubber tubing; a pendant being loosely connected to the further end of this. Probably the most reckless case occurred in a bedroom where the bracket had been removed from the wall. A long length of flexible tubing was attached to the nosepiece without any tap, and the other end of the flexible tubing connected to the bracket, which was being used for warming a baby's food. Many cases were also discovered of the fixing by outside fitters of so-called flueless geysers and other types of undesirable apparatus; but as instances of these are of daily occurrence in gas-works experience, they are not included in the above. In practically every case, however, the influence of war conditions was evident; and it may safely be said that in normal circumstances the defects in question would have been duly reported and remedied.

In all instances in which defective fittings were discovered, the consumer was sent the following notice, which generally had the desired effect:

Engineer and Manager's Department,
Newport (Mon.) Gas-Works.

.....192

IMPORTANT NOTICE.
DEFECTIVE FITTINGS.

DEAR SIR (OR MADAM)—I beg to give you notice that the following gas fittings fixed on your premises at..... are defective, and unless remedied a serious accident from escape of gas may ensue.

DESCRIPTION OF FITTINGS.

.....

.....

I should be most pleased, on hearing from you, to quote you a price for repairing or removing these, if you wish my Company to carry out the work; but I strongly advise you in any event to give the same your immediate attention in view of the danger you are incurring while the fittings remain in their present state.

Yours faithfully,

Engineer and Manager.

As a result of the experience obtained, it was decided to use none but solid-drawn brass or copper tubing in all gasfitting work carried out by the Company; and manufacturers of fittings were asked to give a guarantee that this description of tubing would be used exclusively in the fittings made by them. Almost without exception the firms concerned willingly furnished the guarantee in question.

TESTING FITTINGS.

In view of the importance of the whole subject, and the existence or development of leaks in new fittings and apparatus, a system of testing these was instituted at the same time. Fittings in general are tested with gas at a pressure of 4 lbs. per sq. in.; but lighting burners and flexible tubes are tested at 8 in. water-gauge pressure. The necessary pressure is provided by a compressor delivering gas to the district. The number of appliances of various kinds dealt with amounts approximately to 12,000 per annum; and each piece which is found satisfactory is stamped before leaving the testing shop. The total cost of this service is about £40 a year. The fittings found defective amounted at the commencement to 1·07 p.ct. of the total, the chief defects discovered being leaky taps and ball joints. It may be added that, almost without exception, manufacturers of apparatus were prepared to accept the test in the spirit in which it was applied—namely, with the view of providing gas consumers with thoroughly reliable fittings free from leakage, thereby ensuring the continued and extended use of gas, with enhanced profit both to the manufacturer of gas apparatus and the gas undertaking. As a result of the introduction of this system of testing new gas fittings, it has been found that the number of defective fittings discovered is now reduced to 0·28 p.ct., or exactly one-quarter of the original percentage. It is suggested, however, that the makers of gas fittings would find it to their eventual advantage to carry out this work themselves, and to give a guarantee that all fittings or apparatus supplied by them had undergone such a test.

VARIATIONS IN TAPS.

In certain cases, taps which had passed the high-pressure test successfully became leaky after a short usage by the consumer; and during the period immediately following the war the number of such failures became so frequent that the subject was investigated. It is a matter of common knowledge that there are many old gas taps still functioning perfectly after forty and even fifty years of hard daily service; but in some of the modern taps the wear of the plug and seat has been so rapid that often within a few months the whole of the allowance for taking up wear was exhausted, and the tap passed into a permanently loose and leaky condition.

On the surface, perhaps, the question of taps may seem a very trifling matter; but the following points should be remembered:

(1) The tap is a universal and indispensable component of all gas appliances and apparatus.
(2) The tap is, generally speaking, the only moving part in a gas appliance.
(3) Defects, however slight, in the wearing surface of taps generally result in escapes of gas.
(4) The presence of an escape of gas, however small, is undesirable.

In order to ascertain, if possible, the cause of the trouble, taps of various ages and sizes were collected, and, as a preliminary, a chemical analysis of the material of the old and new taps respectively was made. This, however, showed that there was comparatively little difference in composition between the metal in the old taps and that in the new taps. The analyses revealed that the composition varied between the following extremes:

	P.Ct.	P.Ct.
Copper	62·44 to	68·2
Zinc	25·75 ,,	30·35
Tin	0·60 ,,	1·93
Lead	0·93 ,,	2·41
Specific gravity	8·15 to	8·43

The specific gravity of brass varies, of course, with its chemical composition; but in the two following samples

of almost identical composition there is a marked difference in the specific gravity:

—	A.	B.
	P.Ct.	P.Ct.
Tin	1·60	0·60
Lead	2·41	2·13
Zinc	26·27	25·75
Copper	68·00	69·20
Loss	1·72	2·32
	100·00	100·00
Specific gravity	8·43	8·21

This difference in the specific gravity of two samples of practically uniform composition would appear to indicate that the reasons for the imperfection or otherwise of these taps depended rather upon the physical structure of the alloy than upon its chemical composition. In certain other cases the trouble was traced to the presence of sand in the castings, which, naturally, owing to its abrasive character, led to rapid and unequal wear of the plug and seating. In further instances the alloy seemed to be "patchy," and would in certain spots clog the teeth of a file when used on it.

Quite apart from the question of quality of metal employed, there seems to be considerable diversity of practice in the design and manufacture of taps, which is evident from the variation in the taper of the plugs. The following figures, representing actual measurements of the plugs of old taps of from 25 to 40 years of age and of modern taps, respectively, will illustrate this. In the case of main taps there seems to be very little difference between the old and the more modern practice; for in sizes between ½ in. and 2 in. in diameter, the total taper of the old and modern taps as measured on both sides of the plug varied between 1 in 8 and 1 in 12.

Cooker taps showed a great discrepancy, as the taper of the old taps varied from 1 in 12 to 1 in 19·2, whereas the modern taps varied from 1 in 10 to 1 in 12. A similar difference was exhibited by the smaller taps used on general fittings, in the older types of which the taper varied from 1 in 10·7 to 1 in 16, whereas the taper of the modern tap was approximately 1 in 8 in all cases.

The above figures do not claim to apply universally to all makes and types of gas taps; but they indicate clearly that, even within the limits of the collection made for the investigation in question, wide variation existed in the taper of the plugs. Excessive taper is undoubtedly undesirable, on many grounds; while too slight a taper tends to exaggerate the longitudinal adjustment required in order to take-up wear. It would seem, however, that the older practice in respect of taper has been departed from without sufficient reason, and the opinion may be hazarded that reversion to a taper between 1 in 12 and 1 in 16 would be advantageous.

STANDARDIZATION.

There has been a tendency in modern engineering practice towards the standardization of the materials employed in construction; and the question of the desirability or otherwise of standardizing the composition and physical characteristics of the brass used in tubes and gas fittings, as also the standardization of the design and proportion of the working parts of gas taps, naturally suggests itself. The standardization of complex types of apparatus is, perhaps, to be deprecated, on the ground that, to many minds, standardization implies finality, which checks the competition of varying types and their progressive development. In the case of ordinary gas taps, however, it may be assumed that approximate finality in type has been secured; and, in any event, standardization need apply only to the material used and the actual wearing portions, leaving manufacturers free to vary the details of external design.

Very useful work has been recently carried through by this Institution, in co-operation with the makers of wrought-iron tubing, in connection with the standardization of tubes of that material; and it is respectfully suggested that, in conjunction with the manufacturers, who have always shown the utmost willingness to co-operate in matters of this kind, the production of standard specifications for other types of gas tubes and fittings might possibly be considered. It may be claimed in respect of solid-drawn brass tubes that only an alloy of suitable composition will stand the treatment involved in the manufacture of this type of tube; but as against this it may be stated that even solid-drawn tubing has occasionally exhibited defects which are in all probability due to some variation in the composition or physical structure of the alloy used.

CO-OPERATION.

In rendering efficient service to consumers gas undertakings are necessarily dependent to a large extent upon the hearty co-operation of the firms who manufacture gas appliances, apparatus, and fittings. This co-operation is in all cases most willingly afforded by the makers in question; but it may at the same time be pointed out that they labour under an unavoidable disadvantage, from the fact that they do not as a rule come into direct contact with the users of their apparatus. It behoves gas undertakings, therefore, to keep the makers well informed as to the actual working experiences of the consumer. Gas appliances of all descriptions have been immensely improved, both in design and efficiency, during the past few years; but continued improvement will be most rapidly brought about by hearty co-operation on the lines indicated.

INSPECTION.

The general inspection of consumers' fittings referred to above resulted in a continued diminution of leakages due to defective fittings and apparatus, and matters in this respect returned rapidly to a more normal state, thus indicating plainly that war conditions were to a large extent responsible for the deterioration in gas fittings and appliances. The system of inspection, however, although no longer so urgently necessary for its original intention, has been continued, with the double purpose of maintaining the efficiency of burners, cookers, fires, radiators, and gas appliances generally, and at the same time instituting a census of gas apparatus.

It is found that consumers appreciate a visit from an inspector, as evidence of an interest in their welfare; and a better understanding has certainly resulted. Unsatisfactory apparatus falls naturally into two divisions. It may be of a modern and efficient type, but functioning imperfectly, in which case the consumer is asked to give an order for its repair and adjustment, and if he so desire, is furnished with an estimate. In every case this work is carried out on the lowest possible terms. The apparatus may, on the other hand, be worn out or obsolescent, in which case the inspector's visit is followed-up by a canvasser, who is very often successful in securing the installation of new apparatus; and with a view to encouraging this, the Directors of the Company have instituted the policy of fixing free all cookers, fires, radiators, and gas boilers purchased either for cash or on the hire-purchase system.

This work would, of course, in the case of a large undertaking be delegated to a special department, as the magnitude of the operations would justify the expense involved. At Newport, one inspector attends to all the more important and urgent cases; but the remainder of the work is carried out by intelligent co-operation between the members of the inspecting, canvassing, and meter collecting staffs. This, of course, necessitates partial intermission of this special work when other urgent calls are made upon the staffs in question; but up to the present the arrangement has worked satisfactorily, and it possesses an elasticity and adaptability to circumstances which prove highly advantageous in practice.

"OLD-FASHIONED" COURTESY.

In carrying out any system of this nature, a great deal must, of course, depend upon the personnel of the staff to which the work is entrusted. Certain qualities—some inherent, others acquired—are highly desirable, but not always easily obtained. One qualification is, however, absolutely indispensable, if success is to be secured, and this is the possession of the old-fashioned virtue of courtesy. The adjective "old-fashioned" is advisedly used in this connection, as it is unfortunately too often the case that the present generation, with its yearnings after self-expression, is apt to exhibit what it considers independence by lack of consideration for the feelings of others. This tendency is not confined to any one class of the popu-

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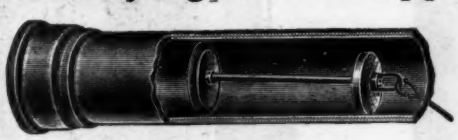

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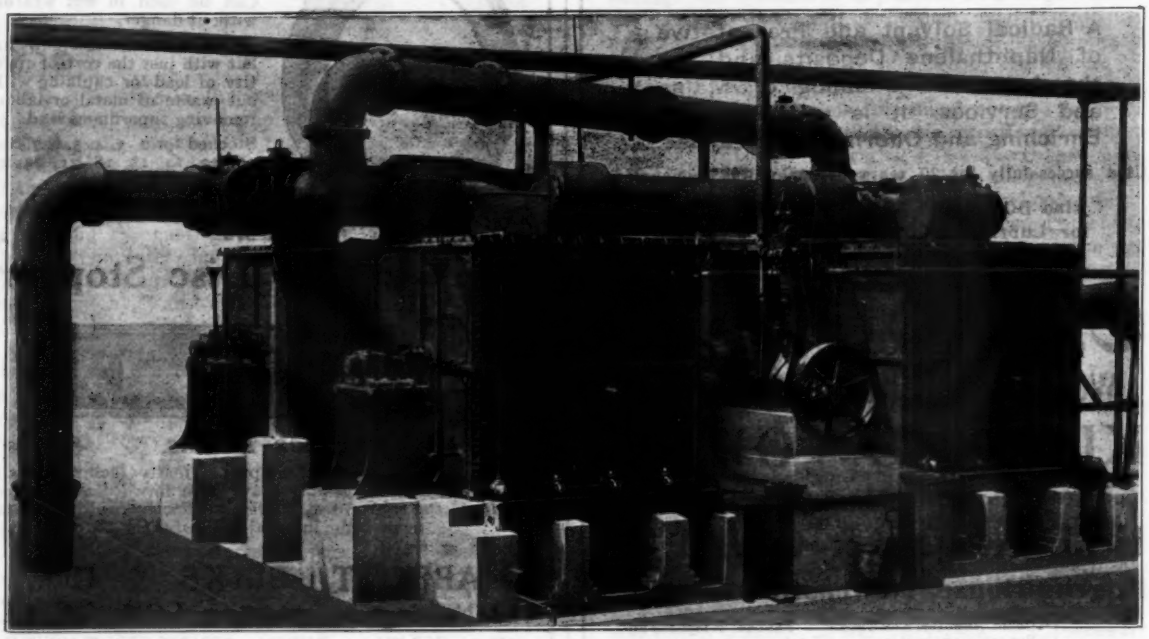

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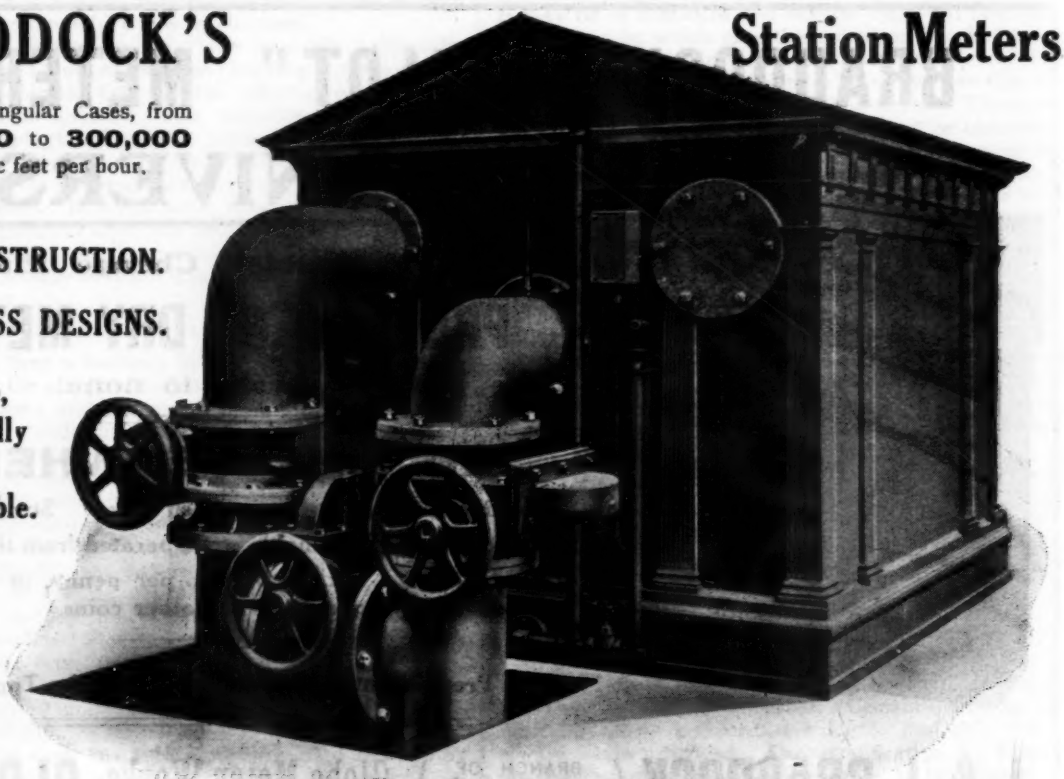

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lation, and is by no means universal; but it certainly limits the range of selection. A further advantage of courtesy is that it is generally accompanied by intelligence.

TECHNICAL TRAINING OF GAS FITTERS.

Another qualification is the possession of sound technical knowledge; and the technical training of gasfitters is a matter which is rightly engaging the very serious attention of those responsible for the conduct of gas undertakings. In the period anterior to electric competition some excellent gasfitters existed. They had never enjoyed the opportunity of profiting by the technical training which is now so generally diffused, but had learnt their trade in the hard school of experience, were thorough in their methods, and under efficient guidance their workmanship was generally sound and reliable. The electrical counterpart of the gasfitter is, however, availing himself more and more as time passes of the present-day facilities for scientific and technical education; and if the gas industry is to maintain its position worthily, it is obvious that the evolution of the modern gasfitter must proceed on similar lines. The same development is taking place in all progressive industries; and rule-of-thumb methods, excellent as they may have proved in the past, must inevitably be superseded by exact methods based upon a practical working knowledge of scientific principles.

Recognizing the necessity for up-to-date methods of training, the Directors of the Newport (Mon.) Gas Company, by arrangement with the Education Committee and the Newport Corporation, secured, in 1912, the establishment of gasfitting classes at the Newport Technical Institute. The curriculum was arranged in consultation with the Principal, and consists of courses in elementary mathematics, elementary science, and gasfitting. The classes in mathematics and science are held in the afternoons, and the Company gives the pupils the time necessary for attending thereat. The gasfitting class is, however, held in the evening, and pupils attend in their own time. The Company pays all the fees; and as that which costs nothing appears to be correspondingly valued by recipients, it is felt that, if only as a pledge of good faith and earnestness, the pupils should make the small sacrifice of attending a portion of the curriculum in their own time. Prizes are given annually on the results of both external and internal examinations; while a special prize is awarded for regular attendance.

The classes are open to other than the employees of the Company; and it is an interesting fact that in one year the best attendance was put in by a pupil who was obliged to make a double journey, totalling some 40 miles, to each class attended by him. Attendance at the classes is not confined to gasfitters and gasfitters' apprentices, but all grades of the Company's employees engaged in any branch of its outdoor activities are encouraged to attend, as it is felt very strongly that competent knowledge of elementary gasfitting, the varieties of gas apparatus, and their fixing and adjustment, are invaluable to salesmen, canvassers, and also those engaged in a clerical capacity in connection with the outdoor department. Now that the Institution's Education Scheme is established, it is hoped that some proportion at least of the pupils may be encouraged to proceed further.

The classes were continued until the year 1917, when war conditions necessitated their discontinuance until 1919, when they were re-opened. The chief difficulty experienced upon resumption was due to reluctance on the part of young men to adopt gasfitting as a vocation. The imagination of youth had naturally been kindled by the war, and every boy worth his salt appeared anxious either to join the Air Force or become a motor engineer. A few boys, too often, unfortunately, mentally or physically deficient, were prepared to enter the more humdrum occupations; but these, of course, could not be accepted. Gradually, however, as the overcrowded state of the more romantic occupations was discovered, the number of candidates increased; and no further difficulty was experienced in that respect.

The efficiency of the classes was, however, seriously handicapped from another cause. The bulk of the candidates had received an elementary education only; and it was rapidly realized that the educational qualifications of the pupils was not sufficient to enable them to profit by the instruction given. This was exceedingly unfortunate, as it deprived a number of boys, excellent in every other respect, of the opportunity of learning a useful trade. No blame can be attached either to the local Education Authority or to the excellent teachers employed by them; but the lamentable fact remains. In the modern theory of education, utility appears to be subordinated to variety, and the curriculum becomes so overcrowded that neither teachers nor pupils are able to do themselves justice. This difficulty is not peculiar to Newport, and has been met in at least one instance by the establishment of special classes; but this is quite impracticable in the case of smaller concerns.

It was necessary, therefore, to select apprentices from the pupils who had attended either the Municipal Secondary School or other institutions of similar standing; and this procedure has been adopted with excellent results. The number of candidates is less; but, on the other hand, the number of failures is correspondingly reduced, while, in addition to this, owing to the higher standard of intelligence and general education, progress is far more rapid. This result has been largely due to the kind and useful co-operation of the headmasters of the schools in question. Their intimate knowledge of the character, capacity, and natural bent of their pupils, enables them to afford boys invaluable guidance in their choice of a vocation, and very greatly diminishes the chances of failure, with corresponding advantage both to the youths and to their employers.

ARGUMENTS IN FAVOUR OF GAS SERVICE.

The chief arguments in favour of gas service may now receive consideration.

The principle of service has for some years past received increased recognition among gas undertakings; and there are undoubtedly sound and substantial reasons for the change which is taking place in the attitude of the industry on this question. In the first place, it must be admitted that, whether for good or ill, the type of civilization now developing tends more and more to produce the individual who expects everything to be done automatically for him. This is an age in which the railway, the motor car, the aeroplane, telegraphy, and telephony have almost abolished the limits imposed on man by time and space; and, as a consequence, man becomes ever more exacting, more impatient of delay and inefficiency, and more inclined to avoid whatever involves worry or exertion.

In addition to this, business engagements and social amusements occupy so much time in these days, that the average man or woman no longer possesses the leisure which obtained in the more spacious days of the Victorian era. As a result, and in spite of the facilities afforded by the telephone, gas consumers are more and more disinclined to lay their reasonable complaints before a supplying undertaking. They may experience difficulty, brought about by some minor defect in, or improper adjustment of, an appliance, and, instead of reporting the matter, they generally attribute it, quite wrongly, to defects in the quality or pressure of the gas supply, discontinue the appliance in question, and cherish a silent grudge or prejudice against gas and all pertaining thereto. It would be possible to enumerate cases of this kind which have come to light as a result of the method of inspection described above; and it is pleasing to be able to record the fact that in a great majority of instances prejudice, often of long standing, has been removed and friendly relations established.

In this connection, it may confidently be asserted that there has been, within the past fifty years, a radical change, which is still proceeding with accelerated speed, in what may be called the environment of gas undertakings. It is a well-known fact in biology that one of the surest indications of vitality in any organism is its power of accommodating itself to a change in environment; and if this power of accommodation be absent, the organism is inevitably doomed. The gas industry—and its competitors would be the last to challenge the fact—is certainly not lacking in vitality. There is every indication that it is capable of responding vigorously to the stimulus of a changed environment; and, as soon as the necessity for the response has been realized, there is no doubt of the result.

In the next place, the increased competition of recent years needs no stressing. It is a factor which necessitates prompt measures and, almost automatically, in-

duces the necessary counteracting resistance. It is referred to here because the service which should be rendered by a gas undertaking is to a large extent governed by the corresponding competitive service.

Competitive Service.

In this connection, attention may be drawn to the fact that, whereas the conditions of competition with oil and coal are practically uniform in different parts of the country, in the case of electricity the severity of competition varies very greatly, and is dependent upon certain factors. A large electrical station can produce energy more cheaply than a smaller station; and in districts where there is a large continuous industrial load, the costs of production of current are correspondingly low. But, in addition to this, it is generally the case that a municipal undertaking attaches more importance to the supply of energy for heating purposes at very low rates, and renders more gratuitous service in connection therewith than can possibly be the case with undertakings which are bound to pay more attention to commercial considerations. Not content with competition, some municipalities actually interdict, and use various indirect methods of excluding, the use of gas.

At Newport, the Corporation Electricity Department lay all services free; fix electric cookers free of charge, including 20 ft. of cable; supply current for heating and cooking at 1d. per unit; make no charge for meter rent; and hire cookers at a rate, inclusive of maintenance and general attendance of every kind, of 16s. per annum. The figures published towards the end of 1925 in respect of the Wimbledon Electricity Department state the average cost of electric cooker maintenance at a little over 16s. per cooker per annum; but more recent statistics relating to Croydon give the average cost at £1 per cooker per annum. These figures are only quoted here for comparison with the hire charge set forth above, to indicate the extent of the service which some municipalities are prepared to render in order to secure the cooking load.

The relative cheapness of gas cooking is undoubtedly a very great factor in its favour; but it is questionable whether its reliability and efficiency do not constitute factors of much greater importance. A great many persons of the class which is prepared to make a trial of electric cooking would be perfectly ready to meet the additional cost, provided that the reliability and efficiency of both systems of cooking were equal; and it is here that the provision of the requisite service, by maintaining efficiency, tells decisively in favour of gas. Even in the case of consumers, however, to whom the cost of cooking is of paramount importance, neglect to maintain the efficiency of the gas cooker brings about a reversion to the use of coal, with consequent loss of consumption.

There are many districts, of course, where serious electrical competition in the heating and cooking field has as yet, for practical purposes, hardly been experienced; and it may be argued that in these areas the provision of adequate service is of secondary importance, or may be indefinitely postponed. Under the new Electricity Act, however, with its pooling of the national industrial load, it may reasonably be inferred that more active electrical competition is likely to be extended to these areas; and experience of the past tends to show that service is always more appreciated when rendered voluntarily, and before competition exercises its compelling force. If, when electricity was first introduced, gas undertakings generally had secured that favour among the general public which has in recent years resulted in very many cases from the adoption of systems of gas service, it may be safely stated that gas consumers would not have been so eager to turn over to new methods. It is much easier, and far more profitable, to create this friendly atmosphere beforehand.

Sales of Appliances.

One of the strongest arguments, however, in favour of gas service, is the remarkably stimulating effect it has upon the sale of gas appliances. At Newport, the sales of gas apparatus for the year 1925 were more than three times as great as those for the year 1921. The town is largely industrial, and the population suffered heavy financial loss during the coal strike of 1926; but, notwithstanding this fact, the sales of apparatus, although not quite as great as in 1925, did not fall far short of that year's figures. In the current year, with reviving trade, there is every prospect of a substantial increase.

The Aid of a Showroom.

In relation to the important question of the sales of apparatus, it may be said that it is impossible to emphasize too strongly the immense assistance which can be rendered by a well-managed showroom as an auxiliary to gas service. It is most encouraging to note the change which has been wrought in the attitude of gas undertakings generally towards this vitally important branch of gas service. When showrooms were first established, it was too often in a semi-apologetic manner, and the exhibits in the windows were hardly calculated to attract the passer-by. It is true that showrooms had for many years been a feature in the offices of gas undertakings; but the commercial possibilities of a shop in a public thoroughfare were for a long time neither realized nor utilized. Yet, great as these factors are, it is questionable whether they outweigh the educational possibilities. A well-managed showroom, with its attractive and instructive window displays, its well-chosen and well-arranged selection of gas apparatus, its demonstration of the artistic and decorative possibilities of gas fires, and, above all, the courteous attention and sound technical advice given by those in charge, probably does more than any form of publicity to make known to the general public the advantages of gas.

Many undertakings, realizing these vast possibilities, have in recent years erected palatial showrooms. Many others, though equally conscious of these advantages, have to be content with more modest premises; but, whether the showroom be large or small—whether it be sumptuously equipped or of the simplest character—its educational possibilities are immense, and if full advantage be taken of these, commercial results will soon follow.

Publicity.

Another great educative agency is the well-organized publicity campaign of the British Commercial Gas Association; and the effect of this may be very greatly increased and supplemented by local advertising on the part of gas undertakings. It may be claimed that showrooms and advertisement form no part of gas service; but the trend of modern development is to combine and interlink the external activities of a gas undertaking in such a way as to concentrate their united influences upon the rendering of efficient service to the consumer, with resultant profit to the undertaking. It is generally assumed that advertisement is undertaken simply with the view of securing profit; but where competition exists, it is necessary to tell the prospective purchaser something about the advantages and possibilities of the article he is being asked to patronize. This may be termed the educative function of advertising; but in respect of it, one condition must be absolutely observed—no claim must be made for the article which is being sold which cannot be fully substantiated in practice. Observance of this fundamental rule is at once good morals and good business, and has the inestimable advantage of gaining the confidence of the consumer, with lasting and profitable business relations.

Somewhat similar remarks apply to the quality of the apparatus sold at the showrooms. Nothing but thoroughly sound and dependable appliances and fittings of good workmanship should be displayed. There is an abundant choice of good material of this kind made by many firms of the highest standing; but a showroom will have to compete with local vendors of cheap and almost worthless fittings, burners, mantles, and glassware. It is impossible to enter into competition with trash of this description; and nothing but patience and persistent education of consumers will prevent its diffusion. More damage, if possible, is done to the reputation of gas lighting by cheap and worthless mantles than by cheap and inferior fittings; and it is well worth while making a speciality of a thoroughly dependable mantle at a low price, in order that consumers may have no excuse for purchasing rubbish. Experience has shown that, by adopting this policy, consumers have been gradually taught that the higher-priced mantles are generally more economical; but it is necessary to attract them to the showroom by means of the cheap mantle, before the

advantages of the better-quality article can be demonstrated.

In the matter of supplying the public with the best and most efficient apparatus and appliances, the interest and duty of gas undertakings and makers of gas apparatus are, to a great extent, identical. The gas industry has been greatly indebted to these firms in the past, and they have generally met the demands made upon them by the vast progress and development in the use of gas. It is more necessary than ever that this hearty co-operation should continue; but it cannot be fully effective unless, as stated previously, every possible information is afforded to manufacturers with respect to the behaviour of their appliances under the stress of daily wear and tear and their general adaptability to the purpose for which they are designed. Occasionally, also, constructive criticism may be forthcoming; and experience shows that this will almost invariably meet with careful consideration from the progressive firms who supply the needs of the industry, and who fully realize the community of interest involved.

CONCLUSIONS.

Experience is valueless unless one draws from it conclusions for guidance in general procedure and future eventualities. For the following conclusions neither originality nor correctness is claimed; but they represent what may be called a mental resultant of individual experience:

(1) No scheme of service can be effective or enduring unless based upon a sound foundation. In the case of gas service, the foundation must consist of the essentials enumerated at the commencement of this paper—namely, a continuous, adequate supply of gas of good quality to every consumer, in whatever portion of the district of supply he may reside. Unless this preliminary condition be satisfied, any attempt at further service can only result in disappointment to all concerned.

(2) It hardly seems possible to lay-down any uniform system or method suitable for the requirements either of every district or every class of consumer. The inhabitants of different areas vary not only racially, but also in habits and requirements. There is all the difference in the world between the conditions of the Metropolis and those obtaining in a North Country or Welsh mining town; while health and pleasure resorts present special problems of their own. It seems advisable, therefore, that each district should be made the subject of independent study before any definite decision is come to, and the physical conformation of the district, the lay-out of its urban areas, and the psychology and habits of the population be taken very carefully into account, in order that a scheme appropriate to local requirements may be elaborated. This scheme need not be a complete one at the commencement; and, as a matter of fact, it will probably be found best to proceed by stages tentatively until a complete and suitable system develops.

(3) The appropriate system having been decided upon, it should be worked-out upon business lines; but at the same time, as much flexibility as may be compatible with correct business principles should be permitted. Consumers are human, and being such possess an invincible repugnance to red tape and undue formalities. If any doubt exists upon this point, it is only necessary to study one's own attitude towards Government forms and regulations, to realize how objectionable such manifestations of officialdom are to the average individual. In former days, those responsible for managing the affairs of the gas industry were, in general, sticklers for their legal rights; and it is to be feared that their well-nigh invariable exaction of the uttermost farthing has left behind it a rankling sense of injustice in the minds of the older generation of gas consumers which they have sometimes transmitted to their descendants. Law and business methods alike are absolutely essential in the present state of society; and there is no intention here to minimize their importance. They must both be maintained; but the more they can be kept in the background in any scheme of service the more will that service be appreciated.

(4) As a further development of the spirit of the preceding paragraph, service should be made as personal a matter as possible. The ideal to be aimed at is that each consumer should feel that he is the special and particular object of consideration on the part of the gas undertaking. This is admittedly difficult; but even if only partially and imperfectly achieved, it is almost more than anything else likely to bring about good relations between consumer and supplier. The average man derives far more satisfaction from the imperfect service of a small country hotel where he is known by name, and where his personal predilections are remembered and catered for, than he does from the faultless service of a modern and luxurious caravanserai where his identity is lost in the humiliating impersonality of a mere number. The moral of which is that even a moderate degree of service will go a long way when rendered by one man to another in a human and personal manner. This is one phase of service which should be particularly applicable in the case of small undertakings. In the case of very large undertakings, the individual is often lost in the organization; and it is in the case of smaller concerns that personality has its greatest opportunity.

(5) Service should be rendered willingly. All service worthy the name is well worth doing; and the carrying of it out in this spirit ensures its being done thoroughly and effectively. Obligations of this kind are too often looked upon either as disagreeable necessities or as perfunctory tasks to be hurried through and disposed of as rapidly as possible; and in either case the sense of real service is destroyed.

(6) It is highly important that the gas consumer should be educated by advertisements, leaflets, brochures, and pamphlets, as well as by showroom displays, exhibitions, and demonstrations of apparatus and cookery, as to the advantages and possibilities of gas, and in order that he should acquire at least an elementary knowledge of the maintenance and adjustment of gas appliances. The British Commercial Gas Association are doing invaluable work in this connection; but if their efforts are to attain the success which is vitally essential to the industry, they should be supported by a local campaign on the lines indicated above. It is impossible to over-estimate the importance of educating the gas consumer; and no one who has experience of the advantages to be secured from even a limited effort in this direction would willingly relax his efforts. Objection may be raised on the score of the expense involved; but there can be very few instances in which, provided a fair period of trial has been allowed, the seed sown has not reaped a satisfactory harvest. It cannot, of course, be expected that brief and spasmodic activity in this direction will be able to accomplish much; but even the most modest methods, if well planned and persevered in, will certainly produce good results.

(7) A properly trained staff take such an important part in the education of consumers that, if for this subsidiary reason alone, it would be necessary to give them the requisite instruction. The principal reason, however, is, of course, the promotion of their technical efficiency, the importance of which is so generally recognized that it hardly needs emphasis here. There is no man who is not benefited by a knowledge, however elementary, of the industry in which he is engaged; for such knowledge is bound to render his task easier, and enable him to perform his work with greater satisfaction both to himself and to others. The present personnel of the gas industry has not always enjoyed the opportunities for education which are now available; but it is highly important that those who are to succeed them should possess mental and educational equipment adequate to the respective positions they propose to fill, and that none shall labour under the ignorance which renders a daily task unmeaning and devoid of interest.

(8) Lastly, but not least, every endeavour should be made to secure unity of effort; and, as far as possible, everybody connected with the gas undertaking, from the highest to the lowest, should endeavour to

carry the ideal of service into his daily work, on the principle that the rendering of service to the consumer is one of the best means of promoting the interests of the undertaking. It is quite true that it is not possible for everybody connected with an undertaking to render direct specialized service to the consumer; but, by making known their needs and complaints and the possibilities of fresh business to the department responsible, invaluable assistance can be rendered. In the same way, all the various outdoor departments, embracing activities as widely apart as mainlaying and advertising, can co-operate to a similar end. Suitable education brings about a realization on the part of the individual of the importance of service; while loyalty to the undertaking he serves should accomplish the rest, and result in that union and *esprit de corps* which are so necessary if the best results are to be secured.

As a final counsel to all those responsible for initiating, organizing, and working schemes of service, nothing is perhaps more suitable than the well-worn adage to the effect that example is greater than precept.

Discussion.

The PRESIDENT: I am sure you will agree with me when I express the opinion that it would have been impossible to find a more fitting paper to conclude our technical proceedings than the one which has been given to us by Mr. Canning. It is full of sound advice from beginning to end. I have listened very carefully to the paper, and had read it previously; and I find that I have practically marked every paragraph as having interested me personally. If I were to attempt to speak upon every little matter which I should like to, I am afraid it would be repeating the paper. There have been several suggestions during the past year that the Institution should provide more and better facilities for the engineers of the smaller and medium size gas-works. Now, gentlemen from the small and medium size works, you have lodged your complaints; fortify your position by giving this paper a thorough discussion. There is ample opportunity for you.

Mr. H. D. MADDEN (Cardiff): I should like, as Mr. Canning's nearest neighbour, to say how much I appreciate the paper which he has just read to us. During the past few days we have had papers on the carbonization of coal in its many ramifications, and highly specialized reports; but after all, if we make cheap gas that is not the end of it. We have to get it to the consumer, and to give him a service which will sell the gas. I regard distribution and consumers' service as being equally important as carbonization; and I would like to say that the recent conference held by the "B.C.G.A." on the examination and inspection of consumers' fittings has thrown a strong light on this important subject. I may say that, in my own case, I went back and reported to my Board; and although we have done a lot of work in this way, we reorganized the department entirely, so that we keep on from day to day inspecting consumers' fittings and advising consumers. I have weekly reports sent to me; and our average of successful calls is in the region of 70 to 75 p.ct. I do not mean to say that apparatus is sold in every one of these houses. It may be that a leaky tap or pendant or some other defect is attended to, or other service given to the consumer. Whether it is a sale or a defect remedied, it is put down as a successful call. I should like to thank Mr. Goodenough personally for the way in which he drew attention to this important matter, and for the manner in which he has assisted undertakings which have put the scheme in hand.

There is one point I wish to refer to in connection with successful service to the consumer—that is the service pipe. Mr. Canning has mentioned it. It is astonishing how many service pipes are broken. In trying to get over this difficulty in recent years, I have made it a practice that, before any service pipe is sent out at Cardiff, it shall be internally oiled with a heavy engine oil. We hope that this will add to the life of the pipe, and also save a lot of corrosion and rust which affects the pressure and volume of the gas. Then there is another factor which is coming in, and that is the high capacity meter. The meters which we have been using for many years past absorb too much of the pressure; and on peak loads it is very desirable that the ports of the meters and the connections should be large enough. I think the high capacity meter, with its low pressure absorption, will help very much in giving the consumer greater pressure—especially on peak loads. There is one other matter I should like to refer to in connection with service to consumers, and that is the relief to road traffic. It is rarely realized how much we are saving the community. There is less haulage of coal to the houses, and there is also not the cartage away of rubbish and ashes

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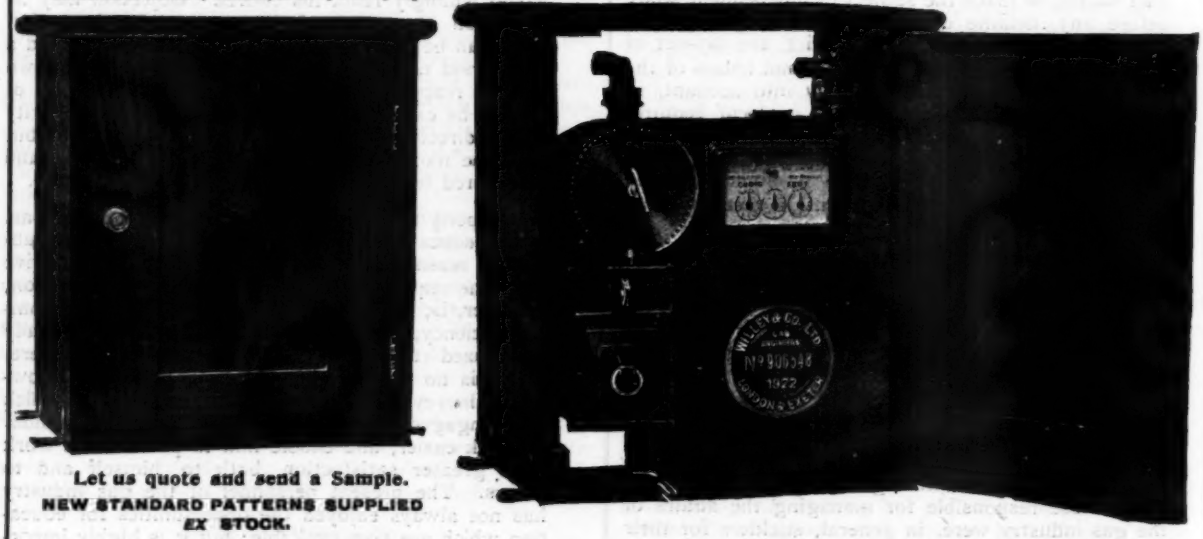

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which there would be if gas were less used. I do not think the industry is given sufficient credit for the amount of money which is in this way saved to the different cities and urban councils.

Mr. F. W. GOODENOUGH (called on by the President): I do not represent one of the smaller undertakings, or else I should have sprung to my feet directly the President sat down, to try and express to Mr. Canning my appreciation of the extremely valuable paper he has presented to us. Like the President, I have marked every passage in the paper, and could spend a long time under-lining and emphasizing the points made. That, however, would not be a very useful way of occupying the time of the meeting, because, as the President has indicated, we want discussion from the general body of members, and you have all heard a great deal from me on this subject of service, which, as you know, the Executive and the whole of the members of the "B.C.G.A." have so much at heart. It is a great satisfaction to have a paper of this value on the service side of the industry, presented to the Institution, and presented in so able, interesting, and thoughtful a manner, with such broad-minded understanding of the essentials of service and of its necessity to the industry as a whole. It was, of course, the appreciation by the members of the Institution of Gas Engineers of the importance of service and publicity that led them to bring about the formation of the "B.C.G.A.," which is an off-shoot of this Institution, and was only founded as a separate body because the Articles of Association of the Institution did not make it possible to carry on the work which that Association does carry on as a branch of the Institution itself. I should like to think that the whole of this paper, and particularly its masterly summary and conclusions, will be read, marked, learned, and inwardly digested, not only by every gas engineer and manager, but by every gas director and by every member of a gas committee from John O'Groat's to Land's End.

It is rather lamentable, when you think of it, that it should really be at all necessary to-day to preach to the industry the gospel of service to the consumer; but as Mr. Canning has pointed out, unfortunately the gas industry as a whole has only come to see the importance of service under the pressure of competition. That is a lamentable fact; but it is the truth. We do want everyone in the industry to-day to realize that efficient service is profitable in itself, and should have been undertaken by the whole industry years ago—long before any question of competition arose. It is the duty of a monopolistic public utility to develop the service that it can give to the community, quite irrespective of whether it has competition to meet or not and it is profitable to every undertaking to develop service, whether it has severe competition or moderate competition, or no competition at all. Service is right and profitable in itself, and should not be merely introduced under the fear and panic created by intensified competition.

I would like somewhat to emphasize the importance which Mr. Canning has given to the training of the personnel in the industry as the basis of service. The education of the staff is of vital importance. Mr. Canning was rather pessimistic about the possibility of getting courtesy shown by employees to-day—the newer generation of employees—to consumers. I do not share that pessimism. My experience is that, if you set the example right throughout the undertaking, if you impress upon your staff the fact that the satisfaction of the consumer is the basis of the whole business—that it is the consumer's money which pays the wages and the salaries and the dividends of the undertaking, that there is no money to come from anywhere but from the consumer, and that if the consumer is not satisfied by courteous and efficient service there will not be any money coming in for the payment of anybody—then courtesy and good service will be given to the consumers. That first appeal is to the selfish side of human nature; and then there is the further appeal to the better side of human nature, which realizes that friendly relations are very much happier and better—more ethically as well as economically sound—than unfriendly relations. My experience is that you can get from your staff that full courtesy and consideration towards the consumer which are so essential to business. We frequently receive from our consumers letters showing their appreciation of this. I have one in my hand at the moment which it is very cheering to receive, as an indication of what a competent staff can achieve. I do not refer to that letter in any spirit of patting ourselves on the back. I am perfectly certain there are undertakings throughout the country which receive similar expressions of satisfaction from their consumers. I only mention it as emphasizing the value to the undertaking of courteous service. I am quite satisfied that, if you go the right way to work, you can get the right attitude of mind on the part of your employees towards your consumers. As I have said, I have marked practically every paragraph of this paper, and should have liked to talk upon it almost *ad lib.*; but I am not going to say anything more, except again to congratulate the Institution upon having invited Mr. Canning to prepare this paper, and Mr. Canning himself upon having done it in so thorough and statesmanlike a manner.

Mr. H. R. S. WILLIAMS (Altrincham): If any proof were needed of the importance of this subject in the minds of gas engineers, I think it will be found in the numbers that have attended on this last morning of the meeting to discuss the subject. I do not propose to deal with many points in the paper; but there are one or two I should like to emphasize. Dealing with service pipes, I have for some time always specified a somewhat heavier gauge than steam strength for service pipes, and have adopted for some years past what is now the Institution specification for puddled wrought iron, with, I think, beneficial results. The paint generally used by tube makers is, in my opinion, rather worse than useless, because it may give a false sense of security and offer no protection whatever to the tube. Therefore I have for a long time specified that all tubes are to be coated, outside only, with Angus Smith's solution; and in cases where the ground is wet, and appears to be of a corrosive nature, we wrap the tubes in hessian, and coat in addition. I think a little extra money spent on service pipes in the first place not only reduces leakage, but results in a better supply to the consumer and gives more satisfaction in every way.

With regard to the education of the fitters, which is made such an important point in the paper, it is an easy matter to educate fitters who are just starting. They have the facilities in most cases for learning their trade at night schools; and my Company have always been very generous in their treatment of the employees, in paying travelling expenses and providing books, &c., for the young apprentices. But it is more difficult in the case of the older men; and it may be of interest to members to hear of an innovation, as far as we were concerned, which my Company adopted two years ago. We found a difficulty often in getting at what the consumers thought of the Company. The management are not in direct touch with the consumers in the same way that the meter inspectors and the fitters and the distribution men generally are. So we decided to hold every month during the winter a meeting of the whole of the distribution department. The Directors generously offered to provide refreshment after each meeting. The meetings are held in the evening in the men's own time. At these meetings we have some sort of paper, generally contributed by the men themselves, unless the subject is a very technical one, and then it is dealt with by one of the members of the staff. We have been very surprised at the talent displayed by our men in preparing and reading these papers. Blackboard illustrations are given, and all sorts of subjects in connection with distribution are discussed. After the paper there is a discussion which is always well maintained; and the men are invited to bring forward questions of difficulty which they have to deal with in connection with the consumers—questions of dissatisfaction on the part of the consumers, and so on. I feel sure that these meetings have been a great help not only to us, but also in our treatment of the consumers. I say it was an innovation to us; but it may be carried out at many other places. I have found great advantage accruing from it. We have not yet adopted the house-to-house canvass which was advocated recently by Mr. Creasey at the "B.C.G.A." conference; but we have been going into the subject. I would like publicly to thank Mr. Goodenough and Mr. Creasey, of the Gas Light and Coke Company, for the great amount of trouble to which they have gone, and for the way in which they have freely offered help to anybody who is undertaking the same class of work. They have given all the assistance in their power to me; and I would like to thank them for the way they have helped the smaller undertakings in work of this sort. I thank Mr. Canning sincerely for his paper.

Mr. B. A. LEWIS (Carmarthen): As representing a small undertaking, I should like to express the pleasure and gratification we have had this morning in listening to the paper by Mr. Canning. A good many papers have been read here which have been interesting and instructive to the large undertakings; but we smaller concerns have only been interested in them to a limited degree. This morning, however, we have listened to a really practical paper so far as service is concerned which is equally interesting to small and large undertakings; and I think I can say with safety that if the smaller undertakings will carry out the scheme which has been so ably put forward by Mr. Canning, they will greatly increase the value of their undertakings. I had a scheme of free maintenance for twenty years—*i.e.*, we maintained the burners free of charge, and simply charged for the material supplied—and I think I can claim that the satisfactory position of my Company is largely due to the service we have given to the consumers. We are an old concern, and have had to overcome a considerable amount of prejudice. As Mr. Canning has said, this prejudice has passed through generations; and in our case it has certainly been handed down from generation to generation. However, I think it has now been overcome; and, in spite of competition, our business is still increasing. We have instituted a house-to-house canvass which will be in operation when I get back.

Mr. W. S. MORLAND (Gloucester): I also should like to thank Mr. Canning for a most useful paper. I do not wish to refer to much of it, because I agree with all he has said; but there is one point to which it might be useful to call attention. In our district we are having road surfaces put down which

are very expensive. In many cases they are making concrete roads; and we have been requested by the Local Authority to lay mains in the footpath, one on either side of the road. We went into this just recently, and found the capital outlay would be increased by about 75 p.ct. for supplying a similar amount of gas. It occurred to me, and I discussed it with our local Surveyor, that before these surfaces were concreted it would be very much better for us to lay conduits across the road, so that if we put a suitable size of main under one footpath, we could thread pipes through the conduits to supply the other side of the road as the demand arose. I am speaking of housing estates particularly; and I arranged with the Surveyor that if he would mark the positions where he would want a supply, I would lay 3 in. agricultural pipes under the concrete road, so that when the services were required we could lay them in the agricultural pipes, threading our pipes through. We have done this, and have a mark on each side of the curb showing the position of the agricultural pipes, which do not go right up to the curbs. Thus we only have to do the little excavating from the curb to the beginning of the agricultural pipes. Another point is that on these concrete roads in future they will not use the heavy steam roller which they have done in the past. Our experience at Gloucester has been that they thoroughly saturate a road with water, and then put a roller weighing probably 17 tons over the surface. Then we find our services have been sunk, and we have at once to make good the defects so caused, with the result that the public complain that the road has just been made up, and then the Gas Company come along and break it up again. Therefore I am interested in this inasmuch as with these concrete roads there will not be that trouble caused to service pipes in future, and we shall be able to get at our services from the side of the road. I have reason to believe that this will be a good system. Of course, there is the risk that if a leak occurs under the surface it may mean a little trouble; but the gas would not get into the houses, as we do not propose to put the conduit right up to the houses, but just near the curb on either side.

Mr. F. C. BRIGGS (Dudley): I also speak as representing a small undertaking, to express my appreciation of this paper. The subject is such a wide one that one could range over it for hours; but I do not propose to do that. I will confine myself to asking the author one or two questions, and making one or two observations generally. We are to be congratulated upon having had such a masterly and literary paper from Mr. Canning on this subject; and I particularly like his summary at the end—more particularly, perhaps, the first paragraph, in which he emphasizes that the basis of the whole industry is to provide a good supply of gas. This emphasizes the importance, as has already been pointed out, of this Institution, because however good the other organizations associated with the Institution may be, the Institution of Gas Engineers must be the foundation of the whole industry; and it us up to every one of our members to see that this is maintained by their own personal service and efficiency. A most interesting point in the paper is the cost of testing appliances and fittings. It is a thing which I have had in mind for some time, that every fitting ought to be tested. But he gives the cost at £40 per annum; and I should like a little more information about that, because it seems to me that the testing of taps, fittings, &c., would be a most intricate matter, and would cost considerably more than that. The author says the makers ought to do it. That is no doubt a "sprat to catch a mackerel;" but I should like to emphasize the point that makers ought to do it, although there are some who now will supply you with fittings guaranteed to be tested. This, however, is done at the factory.

I am glad Mr. Canning has mentioned solid drawn tube. I have for some time specified this, and bought it for our own use; but we have found that it splits, and upon inquiry of the makers one is told some rather difficult technical terms which one does not always understand. The makers often refer to annealing or normalizing, and various other terms which enter into the making of solid drawn tubes; but although "solid drawn tube" sounds well as an expression, we have to get right down to a material which will not split. The author also mentions the question of taps. The most important thing about a tap is the hole; but many taps that one sees on fittings from quite reputable makers practically have not got a hole. Sometimes the hole is filled with grease which one can remove; but you cannot expect the gasfitter to go to the trouble of removing grease from taps. At the same time, more often than not the trouble is with the castings; and the holes in the inner and outer parts do not coincide. Sometimes there is no hole at all. But there is a movement to improve taps and get a clear round bore, which is an excellent thing. If we can get good gasfittings, undoubtedly we shall have gone a long way to providing efficient pressure at the gas burner nipple, which is where we want it. I do not quite agree with the author that war conditions are responsible to a great extent. In my own district we have had difficulties which are due to bad gasfitting in the days gone by; and that is a thing we have to avoid.

With regard to service pipes, we find the main corrosion is on the outside; and in taking out a long run of pipes during a reconstruction of roads, we came across some pipes laid in the past on the old method of pitching, which is excellent. We have resorted to this old method wherever we are laying down reinforced concrete roads, because we have found the main corrosion is on the outside. I should like to ask the author whether he puts any limit to the length of pipe he fixes free. We put a limit of 20 ft.; and we find, roughly, that the cost of fixing equals the profit on the appliances, and we get nothing out of the transaction except the gas consumption. An important thing is the personnel and co-operation among the men. It is a most difficult thing to secure real co-operation among one's men, and to maintain interest in a dull routine job like that of the gasfitter so that there is constant thought for the company's interests. However much one may do, it is difficult to maintain this interest; and I would like to ask the author if he has ever thought of the effect of a commission or bonus to gasfitters for any sales made as the result of inquiries they bring in. We have tried it; and we think it works well. Again, the question of the training of the men is most important; but the author, I feel, has hardly touched the question of training maintenance men, because this is a separate matter. One cannot constantly use gasfitters on maintenance work, because it is more costly. Moreover, it is an advantage to be able to send the same man to the same house every time, because he then knows where the burners are to be found. I think the training of gasfitters is a comparatively easy matter compared with the training of maintenance men. It seems to me that the maintenance man has to be of a peculiar type—a man who is courteous and efficient, but who, on the other hand, really has not too much ambition. It is not a job that leads to a more lucrative salary in the end. There are types of men who are satisfied to do maintenance work, and do it extremely well; but it seems to me that the maintenance section is the most difficult one. I am wondering whether a scheme of training growing boys as maintenance men would prove successful; but I am dubious about it.

Mr. Canning made a point in the paper which I think he ultimately contradicts. He says in one part that the service which should be rendered by a gas company is to a large extent governed by the extent of competitive service. I rather jumped when I heard that; but the author goes on to contradict it by saying that service should be given by a gas company, first because if only in the past we had given good service we might have produced an enormous improvement which would have stood us well now—and I subscribe to that—and, secondly, that service should be given irrespective of the pressure of electrical competition.

Mr. F. G. SHAW (Buxton): I was interested in Mr. Madden's remark that the question of service is as important as that of carbonization. As one whose early experience was in connection with works practice, I have come definitely to the conclusion that distribution is going to be 75 p.ct., and carbonization 25 p.ct. As to the number of visits of maintenance men to consumers, I do not know whether Mr. Canning has had any consumers objecting to the number of calls of maintenance men—say, one per month. In my district, I should find a great objection on the part of consumers to too many calls of this nature. I have also been up against this question: Are we going to take the whole of the work entirely off the consumer, or are we going to do that necessary amount of work for the consumer which will help him to maintain his apparatus in reasonable order? That is a very great point. There are some people whose apparatus would be out of order the day after the most competent fitter had been round; and, again, I do not think it is generally realized that there is quite a considerable knowledge of how to adjust gas apparatus on the part of the larger consumers. There are some people who know perfectly well when they require a hard flame or a soft flame with various gas-consuming appliances; and it sometimes needs a very great deal of knowledge to adjust the apparatus. Yet many people can do it. I should like to know if any engineers present have actually gone to any consumer's house and personally inspected the fittings and adjusted them, and then re-visited the house later—say, the following day—or allowed one of their best men to adjust the fittings, and then inspected the latter themselves the following day.

It is a most difficult thing to adjust apparatus and fittings and ensure their remaining so for any length of time; and I was very much surprised to hear Mr. Briggs say that he did not think gasfitters should be used for this work, as they were more expensive. I think the very best gasfitter I have is only just about good enough for maintenance work. An extraordinary idea appears to be current that a high degree of technical education necessarily increases the competence of handicraft work. I do not think it does. Some of my best gasfitters are by no means the best technically trained men. In fact, my best man, whom I would send to the most important job, would not be able to pass the elementary stage of the gasfitters' examination. Then there is another thing with regard to the psychology of the consumer. It is a great word to-day, of course; and it is a term we must use, I suppose. I find in my experience that even a very good class of consumer looks with respect to a foreman or a working man in the matter of

the suitability or otherwise of the apparatus he is having installed. You may have a first-class showroom man talk to your consumer, or you may take the man to the showroom yourself; but what you say will not give the impression which is given by a competent workman without any frills. You will find his advice is valued, and his influence on the consumer is great. What that man says is often what you are judged by.

Mr. C. S. SHAPLEY (Leeds): I want to say how much I appreciate Mr. Canning's paper. One of the speakers said that distribution work represents 75 p.ct. and carbonization 25 p.ct. Therefore, it would be impossible for Mr. Canning to deal with the whole of the subject of distribution in one paper. He must of necessity have left certain things out; and there is one point I should like to stress in connection with service to consumers—that is, meter rents. I think that one of the things we should seriously consider is the abolition of meter rents. It is one of the things which annoys the consumer, because when he goes into a shop he does not have to pay for a portion of the cost of the scales. We in Leeds have no meter rents, whereas I know one large undertaking which makes the consumer buy his own meter before a supply of gas is given. That is a disservice to the consumer we want to get out of the way. Again, some of our best schemes go wrong sometimes. For instance, it came to my knowledge the other day that 23 men had gone to fix a gas cooker in Leeds. [Laughter.] But it is perfectly easy to understand. Then we thought we had made the system cast-iron and watertight; but 18 men went to fix a cooker in the house of one of our Aldermen. [Renewed laughter.] It is very easy to do this kind of disservice to the consumer; and it all happened in this way. A man went to measure-up; then the cooker was delivered by two men on a lorry; the gasfitter went to fix it; then it was found that the stand had not been placed in position first; and so the whole thing had to be done all over again. That is the sort of thing you want to guard against. I do not mind giving myself away.

Mr. W. C. JACKSON (Neath): Mr. Canning very kindly sent me a copy of his paper some weeks ago; and I therefore feel it incumbent upon me this morning to speak, if it is only to show Mr. Canning that I read his paper before the meeting. One point has not been brought out very clearly on the practical side of this question of service—viz., the psychological side of the reaction of the consumer to maintenance or service. If you do a fellow a good turn, he does not usually, as one human being to another, do you a bad turn in return; and the rendering of good service to the consumer by the gas undertaking has the same effect. The consumers appreciate it, as we all appreciate a good action; and it eventually becomes more or less like a snowball. It accumulates and accumulates until you get these people having complete confidence in your undertaking and in your servants, which is all to the good, financially and otherwise. You begin then to get these people looking to you for assistance in every little matter, instead of going to somebody else and saying they do not know how they manage to work a gas cooker, as their own is no good at all. That is an important aspect which I think should be emphasized at such a meeting as this. Mr. Canning went very carefully through the necessity of working up to the final stage, from the supply of the gas to the giving of adequate service through fittings which have been thoroughly tested and recommended by the gas undertaking, following this up by maintenance so that these things are kept in first-class condition and utilized in a proper manner. Personally, I have found that service does pay. In a paper which I submitted to the Wales and Monmouthshire Institution a few weeks ago, I pointed out that a few years since we in Neath tackled this subject carefully, and that I found as a result that it does pay. The standard of gas consumption in the district has improved out of all recognition; and the feelings of the consumers towards the undertaking have undergone a complete change. As it is said that nothing succeeds like success, so nothing pays like good service. We have found this right throughout. The consumption per consumer has gone up tremendously; and there has been no corresponding querying of the price charged on the accounts.

One point we had to meet in my district was the question of the local plumbers. We are a municipal concern, and were up against the local plumbers. We made them understand, however, that we were determined to go ahead with our fitting work, but that we would prefer to work in co-operation with them. We asked them why they should carry stocks when they could come to our showrooms and select anything they wanted at ordinary selling prices less 10 p.ct., which 10 p.ct. would be credited to them, with the one proviso that our maintenance people should follow-up and see that everything was satisfactory. We eventually entered into an arrangement; and it has worked well ever since. There is the question of putting an experienced fitter on to maintenance work. It has been said that this would be rather expensive; and so it would, where you are trying to run an undertaking as cheaply as possible

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and as efficiently as possible. Moreover, I personally have found that the gasfitter regards maintenance work as rather beneath his dignity; and he does not make the best type of person for the work. The youth is almost hopeless. He is not settled enough for that class of work. We have tried youths of various ages without much success; and finally I engaged several young women between 25 and 30 years of age, and trained them. We have five of these employees; and I can assure you that we could not get better servants. These women are well trained, because in addition to ordinary maintenance duties they attend domestic science lectures at the local technical school as part of their training; so that they are acquainted not only with the maintenance of the equipment, but are qualified to assist the housewife in any cooking difficulties which may arise.

There are two points I want to put to Mr. Canning. First, whether, in his opinion, free maintenance, as commonly understood, is better than the inclusive charge maintenance system which I understand he has in operation at Newport. I make no charge for the services of the ladies we send round on maintenance work. I simply charge for the actual material supplied, which is noted on the maintenance girls' cards—all slot work being charged-up immediately. Other classes of consumers are charged in the same way on their quarterly accounts. Then as to the development of the author's gas fire and gas cooker business. Does he believe in the hire-purchase system as against ordinary hiring? I have heard a great deal about this at various meetings; and I do not think it has been settled either way. Some of the larger companies prefer hiring, but some who are up against financial difficulties, or for other reasons, prefer hire-purchase. I am a strong believer in hire purchase; but it must be coupled with efficient maintenance service.

Mr. T. B. James (Gloucester): I am proud to belong to the Institution; but I am in the lowest grade in which it is possible to be connected with it; and it is only because of the position I hold, in which I have under my control the whole of the distribution department of the Gloucester Gas Company, that I venture to express my great thanks to Mr. Canning, being a near neighbour, for the paper to which we have listened this morning. We have many things in common; and the way in which the businesses are conducted in Newport and Gloucester are very similar. I should like to mention that my Directors are very keen that every attention should be given to the consumer, because they have always realized that the satisfied consumer is one of the greatest assets to the Company. They arranged that a maintenance scheme should be adopted on the basis that on the first visit a charge should be made for all work done, but that on subsequent visits only the material used should be charged for. This scheme has worked very well indeed, and as a result we are more intimately acquainted with the requirements of the consumers, and there is a greater feeling on their part that attention is being paid to them by the continuous visits of the Company's officials. We have also taken a census of the ordinary consumers, and have a tabulated statement, so that we can find at a glance, when receiving a complaint from any house, where it is, and when it was last inspected. In our case, as in another mentioned this morning, no service pipe is laid unless it is covered with hessian, which appears to have very benefical results.

Mr. H. Lees (Hexham): I should like to say a word with regard to Mr. Shapley's remarks concerning meter rents. It would be a pity if it went forth from this meeting that meter rents are anything on a par with the grocer's scales. ["Hear, hear."] When the grocer has to have a set of scales for every customer he serves, we may begin to talk like that. This matter was discussed thirty years ago. The Gas Light and Coke Company at that time had abolished meter rents; but since then they have come back to them. It is only one of those matters which arises about the time of municipal elections, and has no bearing on this paper whatever.

Mr. Ralph Halkett (Sheffield): I would like to congratulate Mr. Canning on his paper, which is full of information. There are many things I would have liked to speak about, but as the discussion has gone on so long, I will only take one or two points. I must confess that he gives us a good lead-off when he speaks of constant quality and pressure. That is essential on a district; and we cannot expect to attain the success we should, no matter what we do in other directions, unless we look after these two things. Testing of taps is an important item, and one about which we should be guarded. We can get taps at varying prices, and we are often induced to accept the cheapest; but they are not always the cheapest in the long run, and I think the method which Mr. Canning has adopted is one which should have very careful consideration from us all. On the question of the training of gasfitters, I am rather disappointed; and yet I cannot say from my past experience that the ordinary lad is not suitable for the technical training that we expect him to have. After all, it is gasfitters we want; and I have found that the best plan is to get men thoroughly trained in the trade, and follow this up with lectures to the men by the inspectors and foremen fitters, and occasionally by the technical members of the staff. The men are thus able to have put before them reasons for doing this or that; and they can also explain how they get out of the difficulties which arise on the district day by day. The greatest trouble we have is to train men capable of taking control of these other men. The difficulty is to find the class of man who is a good gasfitter and is also able to converse with the consumers. Our gasfitters are good practical men; but they just lack the technical training and education to make them efficient in the sense I have mentioned. I have thought out many schemes. It is essential that the men who are going to take charge of the gasfitters should have a certain amount of practical training; and that is the difficulty. I have some members of my staff who would be excellent men for the outside department; but they just lack the practical touch, and cannot put the confidence they should do into the fittter. Perhaps this can be overcome by Mr. Canning's suggestion that we should take lads from the secondary schools, and let them start at the bottom of the ladder; train them as gasfitters; and then advance them to supervision and the detail work of the distribution department. Then we may be able to obtain greater success.

I was rather interested in the remarks of Mr. Jackson with regard to the hire of appliances—whether this should be simple hire or hire-purchase. I have had experience of both hire and hire-purchase; cookers being let out on simple hire, but not fires, which have been put out on hire-purchase. We find the consumer takes greater care of the appliance; and it is not very much for him to pay 50 p.ct. more per quarter than for simple hire, and for the fire to be his own property in three years. We find that this answers very well; and we get rid of thousands of gas fires, water heaters, &c., every year. It is, however, a matter for each undertaking to decide for itself. Local conditions govern it to a large extent.

The President: We have had a most interesting discussion; and I am not going to take any part of Mr. Canning's duties in reviewing it. But Mr. Lees has very properly drawn attention to a certain remark; and I also wish to draw attention to a similar remark, and to challenge it in perfect good humour, because I realize that, as President, I must be impartial. But I must say that I cannot sit still and allow the statement to go forward from this meeting that it is competition alone which has compelled the gas engineers of this country to give service to the consumer. ["Hear, hear."] I am strongly of opinion that service to the consumer begins at the gas-works. I am a gas engineer at top, and middle, and bottom; and I trust I shall remain so to the bitter end. It may be that it is now 75 p.ct. distribution and 25 p.ct. works. Well, has it got to be a case of "Rattle his bones over the stones; he is only a gas engineer nobody owns"? It is just as true to-day as when Newbigging made the statement that your dividends are made on your works. I admire to the utmost the intensified interest in distribution; it is necessary. But if you ever once lose sight of the question of efficiency on your works, that is the time when your competitor will hit you. [Applause.]

Mr. Canning, on rising to reply, said: I should like in the first place to thank the President and the other speakers for all the kind things they have said with regard to my paper, and to assure them how much I appreciate these remarks, and how greatly they encourage me. When I set out to prepare this paper, I was afraid that what I had to say was of such an uninteresting and superficial character that it would not provide anything worthy of the attention of the Institution. But I adopted the policy of laying my cards on the table with the view of inducing others to be equally frank; and I think the information that the paper has brought out will prove of value to all of us—and especially to myself, because I came here with the hope of learning something, and I have certainly not been disappointed. Mr. Madden raised an important point when referring to the high capacity meter. It will be absolutely essential, if we are to meet the very big peak load which obtains in cases where consumers use gas extensively for heating and cooking, to adopt this type of meter. Mr. Goodenough is, I believe, a prominent member of the Rotarian movement; and he has very rightly adopted their motto that "He profits most who serves best." Undoubtedly, this is a point that we should take into account in considering all schemes of service—namely, that you are going to profit by adopting service. That has been our experience in Newport; and from what members have said to-day, the experience has been the same elsewhere. Mr. Goodenough represents me as being rather pessimistic as to obtaining courteous candidates for training as gasfitters; and I am glad to hear that he holds the contrary view, because if we are to succeed in rendering efficient service to the consumer, I think that courtesy comes first. The gasfitter is to a large extent the ambassador of the undertaking to the consumer; and unless he is acceptable to the consumer, the rest of his efforts will fail. Mr. Goodenough also raised the important point of voluntary testimonials being received from consumers. It is pleasing to be able to say that we have had a similar experience. It is very gratifying to us to receive from consumers increasing numbers of letters, since we commenced active endeavours to render the consumer service, expressing gratitude for the service given and approval of the workmanlike and practical manner in which the fitter has carried out his job.

It has been rightly pointed out by Mr. Williams that the paint used by makers of pipes is not exactly the best protection that could be furnished for them; and I would say that in the case of my Company it has been the invariable practice of recent years to use nothing but wrapped pipes—especially as in certain parts of the Company's district the nature of the ground is such that corrosion proceeds very rapidly unless steps are taken to counteract it. With regard to this matter, I should like to refer to the fact that in modern road making it is often the custom to use a heavy substratum of ashes which proves exceedingly destructive to gas and water pipes. There is a case at the moment in connection with an estate being laid out by the Corporation. On behalf of both the gas and the water undertakings, strong representations were made, but no redress could be obtained; and both departments are now adopting the method of laying immediately around their pipes a considerable amount of lime mixed with gravel, in the hope that the danger may thus be minimized. Mr. Williams also raised the point that the education of the young apprentice for gasfitting is comparatively easy, but that it is difficult to deal with the older men. I quite agree with that. Having now the opportunity of doing so, there is an appeal I should like to make to this meeting with reference, not exactly to the older men, but to men of mature age. My Company have engaged a number of comparatively young gasfitters since the war; and I found out incidentally that in many instances the training of these men had been interrupted through their having volunteered their services in the war. One of them was brought before me a little time ago for having left an escape behind on a consumer's premises; and I questioned him, and found out a fact I was not aware of before—that he had been granted a commission in the field. But his training had also been interrupted at a critical point by his being called-up. I think we owe it to these men to give them an opportunity to make good their training. ["Hear, hear."] It has been done in the case of the man in question; and in all probability he will eventually make a very good gasfitter. It is, however, a difficult matter to deal with. To meet such cases, I suggested that the men should join a gasfitting class; but a deputation of them waited on me and said it was rather a loss of dignity to them to have to sit down with boys again in order to learn their trade. On making representations to the Education Committee, they have established a special adult class to meet the case of such men.

Mr. Lewis and several other speakers have referred to the question of free maintenance and charging for material only. At Newport we make an inclusive charge of 2s. per nozzle per annum; but a short time ago, in order to give consumers freedom of choice, the option was granted to them of having labour given free—materials only being charged for. Very few have availed themselves of what one might call this "sporting offer." Personally, I think the reason is that the 2s. inclusive probably works out a little cheaper than the materials would run to. Mr. Morland has made a most interesting contribution to our information with respect to the laying of services in concrete roadways. The provision of conduits for the purpose is admirably calculated to meet the case. There is only one point in this connection that occurs to me as calling for consideration. In these long main roads, the houses are often placed a considerable distance back, and the roads themselves are exceedingly wide. The question then arises whether the service will not be inordinately long, and perhaps break the pressure down at times of exceptional consumption. Of course, everything depends upon the circumstances of the particular case.

A question has been asked by Mr. Briggs as to the cost of the testing of appliances. I was surprised myself to find, on going into the matter, that the cost is so comparatively low. The method of testing is very simple. A meter is connected to a long rail provided with tee pieces, so that a number of fittings can be connected at the same time; and the meter reading will to some extent indicate the leakage. But in addition to this, the fittings are thoroughly tested all over with a pilot jet, in order to make sure that there is no escape of gas. Like Mr. Briggs, I have had experience of cases of solid-drawn tubing splitting; and I certainly think it is advisable that something should be done to standardize the composition of the metal used for such tubing, and possibly also the method of manufacture. I agree with Mr. Briggs that war conditions are not entirely responsible for the difficulties we have experienced with regard to gasfittings; but I do not think it can be denied that the public agitation which occurred a short time ago—after the end of the war—with reference to this matter was to some extent brought about by the exceptional conditions following the war. Mr. Briggs asks whether any limit is imposed in the matter of the length of piping provided in the case of the free fixing of cookers and other apparatus sold by the Newport Gas Company. No limit whatever has been imposed, because in a great many cases no pipe needs to be laid, as it is already there. It is quite true we have an occasional instance in which the consumer obtains a considerable advantage; but on the whole, if you go into every case, you find that the average will run out to something near the 20 ft. mentioned by Mr. Briggs. The same speaker has referred to the question of commission to gasfitters; and this has exercised my mind, and the minds of a great many other people. No doubt it would result in an accession of business; but the point arises of how much time the man would devote to gashtting and how much to canvassing. It is a difficult matter to decide; and I would rather somebody else made the experiment.

A further important subject raised by Mr. Briggs is the training of maintenance men, which has to some extent been answered by Mr. Shaw. There is evidently great divergence of opinion on the point. The maintenance man requires specialized training in the matter of the adjustment and cleaning of all apparatus, but not such a complete training as the gasfitter. He certainly needs to be not only a courteous man, but a man with some individuality. For instance, in a particular district served by my Company we had great difficulty in getting people to have their burners maintained; and it was entirely due to the particular maintenance man going round there. We changed him for another man; and the second man obtained orders for maintenance from no less than twenty consumers on the first day. I should not like to express any definite opinion upon Mr. Shaw's statement as to the relative importance of distribution and carbonization. I think that is a very vexed question; but there is no doubt on one point, and that is that distribution is assuming increasing importance. Perhaps I might put it in another way. We concentrated enormously on works and carbonization in the past, and rather neglected the other side; and now we have to make-up the leeway. Mr. Shaw asks whether consumers have objected to the number of calls of maintenance men; and we have had some remarks from Mr. Shapley on this point. There is no doubt that certain consumers do resent the calling of a number of representatives upon them. Here you enter into the difficult question of psychology, which I have tried to steer clear of in my paper. One consumer likes attention; and another may not. In a small undertaking you are able to differentiate between the various consumers; but in the case of a large one, this is very difficult. Mr. Shaw has also raised another point on which I hardly feel competent to speak; and I think it would form a subject for another paper by somebody on a future occasion—namely, are we going to do all the work for the consumer, or to help him only to maintain his apparatus in reasonable order? I agree absolutely with all he said with regard to difficulties of adjustment. The maintenance man has to adjust in the day time, under conditions of pressure varying from those obtaining in the evening. I have tried to meet this at Newport by giving the men training in the adjustment of burner flames at varying pressures. It can be done by means of a weighted gasholder, with which you can show him exactly what the difference is when the pressure is raised or lowered. That is about all that can be done in the matter. Above all, I think we must agree with what Mr. Shaw has so truly said—that we are very often judged by the statements made by the gasfitter to the consumer.

The question of disservice has been raised by Mr. Shapley; and while I quite agree with him that meter rents apparently irritate the consumer very considerably, still, as Mr. Lees has correctly pointed out, we have to supply a measuring instrument for every individual consumer; and this is a big matter. Mr. Shapley's point brings forward a rather interesting fact. I expect others have had the same experience, that it is not always the big things that irritate a consumer most. Often it is some trifling little charge which one might think he would not notice. A curious fact brought out by Mr. Shapley—it is again psychology—is that 18 men went to fix a cooker at an alderman's house. It is a peculiar thing that if you attempt to do something for an influential person, a director, or a committee-man of an undertaking, matters will always somehow go wrong. [Laughter.] Mr. Jackson, also, has referred to psychology; but that is a question which is entirely beyond me. One can only judge human beings as one finds them, and endeavour to do one's best. There is no doubt, as Mr. Jackson says, that service pays. It raises the standard of gas consumption, and brings about better feeling. The question of local plumbers, again, is a difficult one. I do not wish to say anything about a very estimable body of men; but the plumber is not responsible for the results of the installation in use. While I would not for a moment assert that it is to his profit that it should not run well, the fact remains that he is employed upon remedying defects; and this renders the matter rather a difficult one to deal with. I have not had much experience of it. We did once, at a time of stress, employ a firm of local plumbers, who did very good work for us; but on the whole, I think it is best to employ your own staff as far as possible, and so secure complete control over installations.

Mr. Jackson argues that experienced men consider maintenance work beneath them, and that youths are hopeless. I quite agree; but, on the other hand, I cannot entirely agree with his view as to the employment of women for that work, although I must in fairness say my own experience extended only over the war period. When our men were called up, we put on young women for maintenance, and they were not satisfactory. I think the general experience throughout the country at that time was that getting women to give attention to the work was rather difficult. One of our troubles was

that these ladies were continually asking for holidays in which to spend the substantial earnings they acquired. It is quite possible that under present conditions there will be a better experience; and it will be interesting to hear Mr. Jackson's views later on. If the women acquire a sound knowledge of domestic science, they can afford invaluable aid in the development of cooking. With regard to hire as against hire purchase, I can only say that, after a considerable experience of both, I would rather sell apparatus than hire it. ["Hear, hear."] We are unfortunately obliged to hire, because the electricity undertaking is hiring. I do not like to say it in this hall, but I think they find some difficulty in selling electric cookers. As I say, we are also obliged, as a matter of competition, to hire; but there is no doubt that the man who buys his cooker or fire is an asset to the gas undertaking. The man who hires—although we are glad to have his consumption—is not such an asset. Anyone who purchases is showing his confidence in gas apparatus, and in the undertaking.

An interesting scheme is outlined by Mr. James, under which there is a charge for all work done on the first maintenance visit, before the undertaking takes over a burner. My only doubt about that is as to whether consumers would be in all cases willing to pay the charge; but I gather that his experience has been favourable. Mr. Halkett has stressed the importance of constant quality and pressure; and I certainly agree with him. He has made a very interesting suggestion with regard to the practical training of men being followed-up by lectures. There is no doubt it is not always the better educated man who makes the best gasfitter in the long run—that is, when regarded from the point of view of skill—but in the case of superintendents, as he says, technical training is absolutely necessary.

There is one matter I should like to refer to, which has only come to my notice within the last few days. Some three years ago, we put in gas installations to a series of flats; and the brass pipes laid to some of the gas fires were covered-in, and embedded in one of the patent floor compositions. An escape of gas occurred a few days ago; and to our surprise we found the brass pipe had been completely eaten away by the composition. This may be a question of general interest. Finally, I agree that it is not electrical competition entirely that is driving the gas industry into rendering service, and that dividends are made where they were made in the past. I have trespassed, I feel, to an inordinate extent upon your indulgence; and I should like to thank you for the patient hearing you have given me.

NOTTINGHAM.

Visit to the President's Town: Luncheon Offered by the Corporation.

Nothing daunted by the early hour of 8.15, a large party assembled at St. Pancras last Friday morning, and proceeded to avail themselves of the first-rate arrangements which had been made for their pleasure and convenience. A special train of vestibule coaches was provided; and breakfast was served en route to Nottingham. The weather caused many forebodings; but it eventually entered thoroughly into the spirit of the thing, and was content to rain from London to Nottingham, and thereafter to shine except while tea was being taken.

Arrived in Nottingham, the visitors divided into parties, and left by motor coach to carry out the selected one of several most interesting tours of inspection. Naturally the largest detachment was for the Basford Gas-Works; and there a band of guides was waiting to conduct smaller groups, and to furnish answers to the many questions which interest and admiration evoked. An article descriptive of the works and the Gas Department is reserved for next week; suffice it here to remark that the many sections of the plant were extraordinarily "smart on parade," and that the roominess of the site was the envy of the majority of the visitors.

As for the other parties, we heard many comments upon the organized efficiency of Messrs. Boot's Drug Laboratory and Works, and were astonished at the mechanical ingenuity which produces their world-famous medicines and toilet requisites. Neither this, however, nor the mystic rites of Messrs. Lewis's Hosiery Works were for us; and further comment is perforce omitted. Other happy selections for visits were the Raleigh Motor and Cycle Works, and the Castle and grounds, of which the city is justly proud.

THE LUNCHEON.

A very large party (over 300 acceptances had been received from the Institution alone) sat down to luncheon, in the Drill Hall, Derby Road, as guests of the Corporation of Nottingham. Sir Albert Ball, Chairman of the Gas Committee, was in the Chair; and the Mayor of Nottingham favoured the function with his presence. At the top table, in addition to the retiring President, were Lady Ball, Sir Arthur Duckham, K.C.B., Sir Harold Bowden, Alderman Fred West, C.B.E., Mr. C. F. Botley, Mr. W. E. Price, Mr. J. W. McLusky, Alderman Waddington, Col. W. R. Rook, and many other distinguished guests.

After the Loyal Toast had been duly honoured,

A WELCOME.

HIS WORSHIP THE MAYOR rose to extend a welcome to the visitors. It was, he said, an additionally pleasant duty, because Sir Albert Ball had informed him that most of those attending had brought their wives with them; he thought it was a very wise thing that wives should accompany their husbands when they came to Nottingham. He was glad to learn that those present included members of the Institution from practically every part of Great Britain. He regretted to know, however, that the fact of their arrival only that morning, followed by their immediate inspection of various works of interest, had not afforded them the opportunity of parting with much money to any of the tradespeople in the city—[Laughter]—as the luncheon was to be succeeded also by their immediate departure to Welbeck Abbey. If any of them could arrange, however, to remain in Nottingham, he could assure them that they would find one of the finest cities in Great Britain open to their inspection; and it was therefore with great pleasure that he offered them a civic welcome. It had afforded him pleasure to serve for 14 years as a

MR. AND MRS. WILKINSON AMONG EARLY ARRIVALS AT ST. PANCRAS.

member of the Nottingham Corporation Gas Committee under the chairmanship of Sir Albert Ball; and he was confident in making the assertion that they had the advantage in Nottingham of the services not only of one of the finest Chairman of Gas Committees to be found in England, but also of one of the ablest managers and engineers in the country in Mr. John Wilkinson. [Applause.] The undertaking had further had the advantage of the labours of a very assiduous Committee under Sir Albert Ball's able chairmanship; and he was pleased to say that Nottingham, unlike many other municipalities and private undertakings, made a handsome profit from its gas-working annually, and helped thereby materially to relieve the rates. [Laughter, and a Voice: "Shame."] Although some might say "shame," his contention was that the policy which had been pursued in that respect was right. It might be of advantage to have ladies among them that day; a fear being entertained in some quarters that in Nottingham, as elsewhere, electricity might in course of time altogether displace gas. This led him to express the hope that ladies would exercise their influence in regard to the continued use of gas for cooking purposes. In according the visitors a hearty reception, the Mayor concluded by expressing the hope that their stay in the city would prove of an altogether enjoyable character. [Applause.]

"THE INSTITUTION."

Sir ALBERT BALL, in proposing the principal toast, "The Institution of Gas Engineers," expressed his hearty concurrence in all that the Mayor had said in according a welcome to the visitors to the good old City of Nottingham. Nottingham, he said, had been a training ground for many years for those who were now among the most able gas engineers in the country; and he knew that many of them had been delighted to renew their acquaintance with Nottingham and the Basford Gas-Works. Gas supply had undoubtedly played a most important part in the development of the country's general resources. This had been exemplified not only during the period of the war, but in regard to the progress of trade during times of peace. The British gas industry afforded service of inestimable value during the war period in supplying essential high explosives, without which the country might have been at a severe disadvantage and, possibly, have lost the war. Therefore, those concerned in the gas industry might reasonably claim that they did more to win the war than any other section of the community. But it was not in regard to warlike operations that any of them desired to progress. It was in periods of peace that they wished to achieve prosperity; and they realized that during the recent terrible trade dispute the gas industry did more to provide the homes of English people with means for cooking than was afforded by any other agency. The gas industry had always been in the habit of keeping large stocks of coal in store for eventualities which might occur; and three parts of the people of this country cooked their meals and derived much of their warmth from gas. In a reference to the day's visits, Sir Albert remarked that those conversant with the city's affairs believed that Nottingham would be the most important manufacturing centre in the Midlands in years to come. At any rate they were confident for the present in their claim for Nottingham to be regarded as one of the most beautiful and clean manufacturing cities in the country. ["Hear, hear."] Throughout the length and breadth of the land there was no more acceptable manufacturing centre; and they were delighted that such a representative body as the Institution of Gas Engineers should have honoured them with a visit. They felt that they honoured Mr. Wilkinson, their Manager, in electing him as their President—[Applause]—but they also believed that he was an honour and credit to the Institution. He (Sir Albert) had had the pleasure for fifteen years of working with Mr. Wilkinson—that was ever since Mr. Wilkinson came to Nottingham—and he was never more impressed with his ability than when he heard him deliver his Presidential Address in London. [Applause.] It was one of the best addresses to which he had ever listened at meetings of the Institution. It was full of good common sense; and he was convinced that while the gas industry was represented by men of the skill and ability and the type of Mr. Wilkinson, they need never have any fear of being wiped out by electrical opposition. But he wished to say to gas engineers that if they wanted to afford substantial help in the matter they must not sit talking about it, but must put their backs into the work and do something. They must work hard themselves, and also encourage the young engineers who were coming along. They must afford stimulus and help in every department of the industry, from top to bottom, in order that the greatest efficiency might be secured. By those means only would they achieve success. Men and women to-day were not to be driven. Tact and consideration were necessary; and if they considered their men, their men

AT THE BASFORD GAS-WORKS.

[*E. P. Short & Son, Nottingham.*

would consider them. They would give them of their very best; and if that spirit were maintained, the gas industry would be as prosperous in a hundred years as it was to-day. [Applause.]

Mr. John Wilkinson, who met with a very hearty reception, said that he stood there in the position of a substitute, owing to the unavoidable absence of their new President, Mr. Madden, who had asked him to express his sincere regret at his inability to be present. Sir Albert Ball, their estimable Chairman, had been a very frequent visitor at the meetings of the Institution, and his criticism of matters had always been of a constructive character; and that was the real reason why they always welcomed him at their assemblies. Their hope was that Sir Albert might long continue in his position as Chairman of the Nottingham Corporation Gas Committee, so that he might attend the meetings, and at least do his best to keep them

[*Photo. by Edwin Hadley.*

Alderman Sir ALBERT BALL, J.P.

Chairman of the Nottingham Gas Committee.

in order. [Laughter.] Sir Albert had manifested consistently uniform interest in all that affected the prosperity of Nottingham, including its electricity, as well as its gas undertaking. With such a cordial feeling prevailing in relation to municipal affairs, they could never go wrong. Nottingham had through its many years of progress in public affairs justified its claims to be considered the Queen of the Midlands; and members of the Institution highly appreciated the kindness which had been shown in relation to their reception.

"The Chairman."

Sir Arthur Duckham, in proposing the health of "The Chairman," spoke of Sir Albert Ball's many excellent business qualities, which had been exercised for the greatest advantage of the Nottingham Corporation gas undertaking. He knew of no man who had devoted more time and energy to municipal work than Sir Albert Ball, who had manifested tremendous vitality and whose criticism had always been valuable.

Sir Albert Ball, in reply, paid a warm tribute to the loyalty with which those associated with him on the Committee had acted in the city's interests. He had had the pleasure of presiding over the Committee for a great many years; but he could never have carried out the work with successful results but for the support he had received from his colleagues. He thanked the members of the Institution very heartily for the honour which they had done the city in favouring them with their company; and he trusted they would avail themselves of early future opportunities of again visiting Nottingham and making closer acquaintance with its resources. He was convinced that they would find there was no better shopping centre in the country.

Welbeck Abbey.

The luncheon proceedings then terminated; and the visitors embarked upon a tour of the Dukeries, Nottinghamshire's unrivalled woodland territory. Welbeck Abbey, the residence of the Duke of Portland, Lord-Lieutenant of the County, was the objective in an itinerary which had been admirably planned.

The drive was greatly enjoyed; and though the exigencies of a special train gave only sufficient time for the whetting of the visitors' curiosity and wonder, nevertheless the superb avenue of limes, the deer park, the stately mansion and gardens, and the glimpse of the "township" of Welbeck will long remain a pleasant memory.

Tea was served in the Riding School, after which the party (other than those who had travelled in their own cars) was conveyed by the motor coaches to Elmton and Cresswell Station, where the special train was rejoined. Some left the train at Nottingham; and a very reduced number returned to London, dining *en route*, and discussing the events of what, by common consent, is described as "a thoroughly profitable meeting." It was all that; and much of the success was due to the scrupulous care and guidance of the genial President, Mr. John Wilkinson.

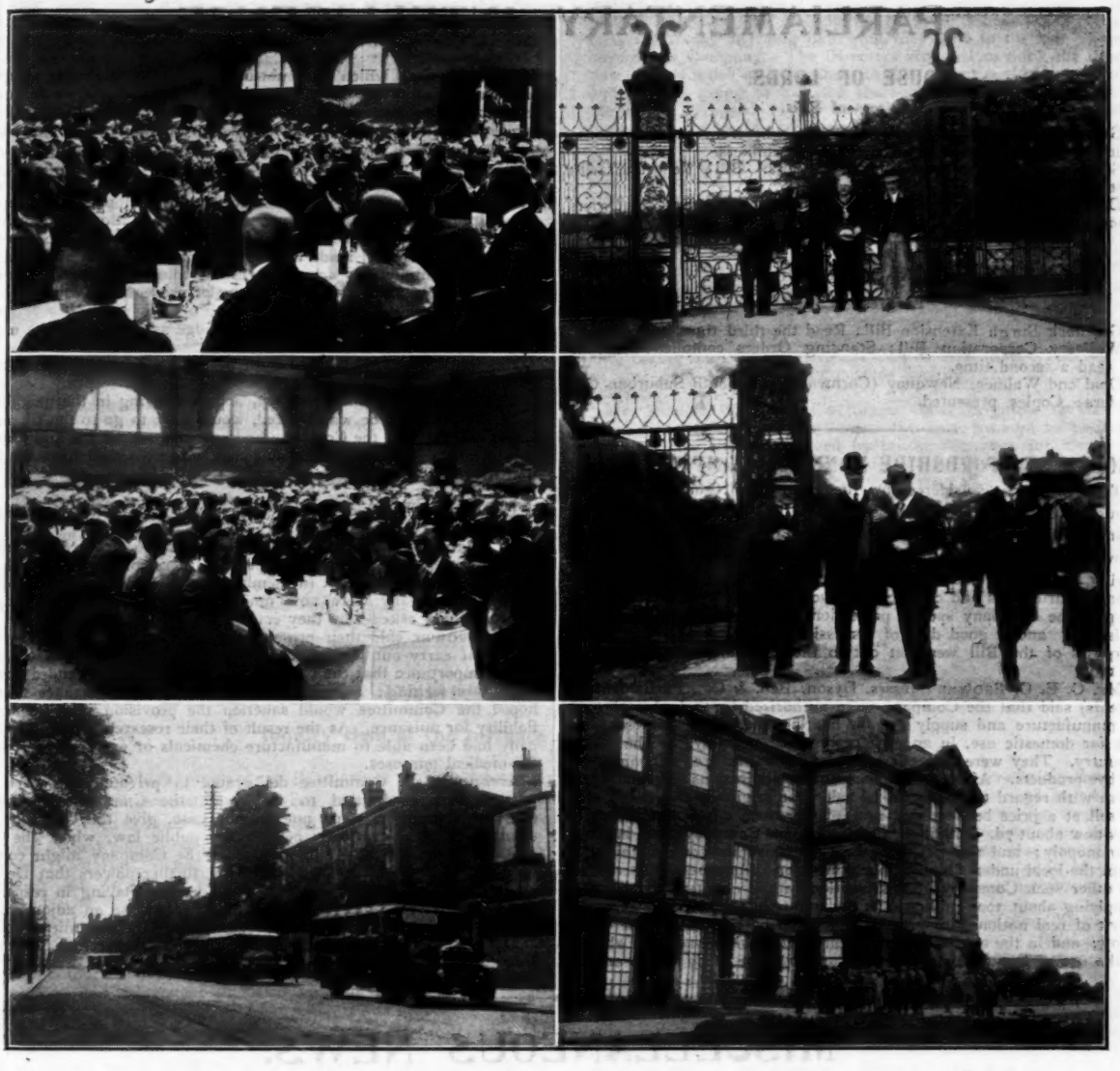
Royal Sanitary Institute Congress at Hastings.—The Royal Sanitary Institute, which for over fifty years has been working in the promotion of the public health, is, at the invitation of the Mayor and Corporation, holding its 38th Congress at Hastings from July 11 to 16, under the presidency of the Right Hon. Sir William Joynson-Hicks, Bart., P.C., M.P., Secretary of State for Home Affairs. The Health Exhibition, which is an important part of the Congress, will include exhibits of appliances, and will be opened by the Mayor on Monday afternoon, July 11.

Scottish Junior Gas Association (Eastern District).—As announced in our "Forthcoming Engagements," the annual outing and visit of the Association will take place at Dunfermline on Saturday, June 25. Members will inspect the Corporation Gas-Works during the forenoon. Ladies will proceed to St. Margaret's Works, where, by the courtesy of Messrs. Hay & Robertson, Ltd., they will be conducted over the linen manufacture and embroidery works of the firm. Luncheon will be served in the Bruce Restaurant, High Street, at 1 o'clock. The usual game of golf will take place over the Pitreavie course in the afternoon. A tour of inspection of the Abbey, Palace Ruins, Pittencrieff Glen, &c., will be arranged. At the invitation of the Gas Committee of the Dunfermline Corporation, members and friends will take tea at Pittencrieff Glen at 5 o'clock.

THE MAYOR.
Councillor Freckingham, J.P.

THE SHERIFF.
Councillor John Hopkin.

THE TOWN CLERK.
Mr. W. J. Board.



VIEWS AT THE LUNCHEON AND AT WELBECK ABBEY.

[*E. P. Short & Son, Nottingham.*

CORRESPONDENCE.

[*We are not responsible for opinions expressed by Correspondents.*]

The Anti-Smoke Act.

SIR,—The Smoke Abatement Act comes into force on July 1; and it is gratifying to realize that, owing to the pressure of intelligent opinion, a Government has at last been induced to deal with a costly nuisance which seriously affects the health and general amenity of the life of the great majority of our population.

If, however, there are people who entertain the belief that an immediate improvement of the atmosphere will occur as the result, they will probably experience a severe disappointment.

It is obvious that the success of the Act depends almost entirely upon its administration. Local authorities, in a word, are now in a position to deal effectively with the nuisance; and if it continues, they will only have themselves to blame.

In the circumstances, it is clearly desirable that they should confer together, and discuss practical measures of common interest.

The first step in this direction has been taken by local authorities in the London area, who have agreed to hold a conference at the invitation of the Coal Smoke Abatement Society; and it is much to be hoped that their example will be followed in the provinces.

NEWTON.

London, June 11, 1927.

Advertising Methods of Mr. George Helps.

SIR,—I am astounded at Dr. Davidson's letter. The advertisement he refers to is not a trading one in the sense he uses the term. Anyway, truth cannot hurt his name. Therefore the main point to me is whether my statement is wholly true. He cannot wish to go back on the evidence he gave in the Chancery Court recently that over 200 therms were produced per ton of coal with the Nuneaton plant working four days and nights at Nuneaton in most carefully and scientifically conducted tests made with the specific object of determining B.Th.U. per ton of coal, and on which no less than twelve persons were engaged, himself in charge.

The very particulars I have given are to be found in the shorthand notes of the case recently published; and if he did not or does not desire such evidence to be published, he should not have undertaken the work.

My opinion is that Dr. Davidson's letter as it stands is not only misleading to the gas industry on a very great question, but grossly unfair to me, for whom he undertook the tests.

I suggest that the exception taken by Dr. Davidson to the use of his name has nothing in fact to do with the reasons (?) given. The advertisement concerned appeared merely in a Nuneaton local paper. Dr. Davidson repeats the "offence" in full detail in the great "GAS JOURNAL" with an immense circulation—this to his still further detriment.

GEORGE HELPS.

Nuneaton Gas Company,
June 16, 1927.

PARLIAMENTARY INTELLIGENCE.

HOUSE OF LORDS.

Progress of Bills.

Greenock Burgh Extension Bill: Brought from the Commons; read the first time, and referred to the Examiners.

Scarborough Gas Company (Consolidation) Bill: Reported, with amendments.

Deal and Walmer Gas Order: Referred to the Special Orders Committee.

HOUSE OF COMMONS.

Progress of Bills.

Greenock Burgh Extension Bill: Read the third time, and passed.

Wallasey Corporation Bill: Standing Orders complied with; to be read a second time.

Deal and Walmer, Newquay (Cornwall), and South Suburban Gas Orders: Copies presented.

SOUTH STAFFORDSHIRE MOND GAS COMPANY BILL.

This Bill was considered by the Unopposed Committee of the House of Commons (presided over by Mr. J. FITZALAN HOPE, Chairman of Ways and Means) on Wednesday, June 15. It includes provisions for the extension of the Company's powers of manufacturing, selling, and dealing in bye-products, and their powers of manufacturing gas and chemical products. There is also a provision to give the Company special protection with regard to liability for nuisance; and a good deal of discussion centred around this. The purposes of the Bill were set out in the "JOURNAL" for Jan. 26, p. 190.

Mr. C. E. C. BROWNE (Messrs. Dyson, Bell, & Co., Parliamentary Agents) said that the Company were authorized by their Act of 1901 to manufacture and supply gas for heating and power purposes, but not for domestic use, in an area represented, roughly, by the Black Country. They were also empowered to manufacture, sell, and deal in bye-products. After a reference to the limitations imposed upon them with regard to dividends, he said that originally they were able to sell at a price between 3d. and 4d. per 1000 c.ft.; but the price was now about 7d. Although a statutory Gas Company, they had not a monopoly; and any power or heating consumer could obtain gas from the local undertakers, who supplied for all purposes. There was no other such Company in this position in the country. They were supplying about 3000 million c.ft. per annum. Considerable research work of real national importance was being carried out by the Company; and in the course of this research work they had been able to make use of bye-products hitherto thought to be of no value, and to produce chemicals which could not be produced by any other company or from any other substance. The powers now sought would enable them to develop and continue this work. As the result of the success achieved by the Company in that direction in the past, they had been able to sell gas at 15 p.ct. below cost, and make their profit on residuals. If they could develop further, and were in a position to sell gas at 25 p.ct. below the cost of production, they would be able effectively to compete with oil imported for fuel purposes; and it would prove to be a development of great national importance. Under their present powers they could not achieve the desired result.

Reference was then made to the provision which would exempt the Company from liability for damages for alleged nuisance, provided that reasonable and practicable means of preventing avoidable nuisance were taken.

The CHAIRMAN: Who would be the judge as to whether the means taken were reasonable or practicable?

Mr. BROWNE said he supposed the persons aggrieved would have to go to Court.

The CHAIRMAN: That is to say, a person living in the neighbourhood, who thought he was injured, would have to go to the Chancery Court and say that the Company had not used reasonable and practicable means of preventing the nuisance, and he would have to show that they had not?

Mr. BROWNE agreed.

The CHAIRMAN asked whether such power had been given to other undertakers.

Mr. BROWNE said he thought the exemption granted to certain electric power companies under Special Orders corresponded with it.

Sir ERNEST MOON, K.C. (a member of the Committee), pointed out that the Company were now manufacturing gas and working-up residuals, and asked why they could not go on as at present.

Mr. BROWNE said their present powers were so limited that they could not carry out the work they wished to do. It was of great public importance that the Company should have the extended powers they were seeking; and it was because of this importance that he hoped the Committee would sanction the provision with regard to liability for nuisance. As the result of their research work, the Company had been able to manufacture chemicals of extraordinary value for medical purposes.

Eventually the Committee deliberated in private, and when the parties were readmitted to the room, the CHAIRMAN announced that the Committee could not, in any case, give the Company the special position, practically beyond the public law, which the proviso would create. They thought that the Company might consult with the Ministry of Health as to what further powers that Department would be likely to agree to the Company having in respect to the proposed researches; and that there should be an adjournment, after which the matter could be brought before the Committee again.

The proceedings before the Committee were therefore adjourned *sine die*.

MISCELLANEOUS NEWS.

MALTA AND MEDITERRANEAN GAS COMPANY, LTD.

A Further Increase in Dividend.

The Ordinary General Meeting of the Company was held on Tuesday, June 14, at the London Offices, 59 and 60, Gracechurch Street, E.C.—Mr. A. M. PADDON, M.Inst.C.E. (the Chairman), presiding.

The SECRETARY (Mr. C. J. Daun) read the notice convening the meeting and the Auditors' certificate; and the Directors' report and the statement of accounts were taken as read.

The CHAIRMAN, in moving the adoption of the report and accounts for the year ended March 31 last, said the latter had been qualified by two adverse influences, independent of each other and quite different in their character. The first had been the incidence of the great coal strike, which, of course, had applied to all undertakings, and had meant to them, as to other gas enterprises, the expenditure of a very considerable amount of money in excess of the normal requirements, in order to meet the emergency. The second disability that the Company had laboured under was purely local and peculiar to themselves. It was the withdrawal of the Fleet from Malta by reason of the disturbances in the Far East, which meant, perhaps, the displacement temporarily of something like 30,000 men, and therefore serious interference with their business. In spite of these two factors—neither of which would, it was hoped, recur—the accounts were of a satisfactory character; the profit being ample to meet their requirements and leave them in a position of stability and encouragement.

THE ACCOUNTS.

Looking at the few items which called for comment, he might say that the extra cost of coal by reason of the strike amounted to just over £1100. A certain proportion of this had been recovered in the residuals, but nothing like what was necessary to re-establish the balance. They had, moreover, during this twelve months increased the expenditure on maintenance by nearly £2000. From the sale of gas practically the same amount had been received as in the previous year, because they had sold the same quantity. That they had not lost ground in the circumstances he had explained was matter for great satisfaction. Before this political disturbance came about, they were gaining considerably in business. A little more than in the year before had been received for rental of meters and stoves and sale of fittings, pointing to a healthy increase in the number of consumers. Residual products had also yielded a little more; but the total gain upon the credit side of the revenue account amounted to only £336, as compared with a year ago. The difference in the profit was even more trifling—no more than £30 odd. The form of accounts had been slightly changed; but all in the direction of making matters clearer; and a profit and loss account had been interpolated. Turning to this, it would be seen, on the credit side, that they had brought £18,779 from the last account, subject to the final dividend for the previous year, the payment of which left them with a sum of £14,427. When this was augmented by some subsidiary amounts and the profit for the year ended March 31 last, they had a total of nearly £31,000. On the other side figured the interim dividend for the year under review, £4352, a transfer of £3000 to reserve account, and £2749 for income-tax, which left a balance, subject to what might be decided upon at that meeting, of nearly £21,000. If they paid the final dividend which the Board recommended, making 7½ p.ct. for the year, they would be left with the not unsubstantial carry-forward of some £16,000. The Company had been secured with regard to coal over the whole of the current year and one month into the year beyond, at a very favourable rate indeed—several shillings per ton less than in the accounts now before them.

A SATISFACTORY POSITION.

The balance-sheet revealed the satisfactory fact that their investments had increased during the year by more than £9000; and at the present time, with a book value of just over £73,000, they had gilt-edged securities which would realize £76,444. This somewhat exceeded the total ordinary share capital of the Company, which was £75,000. It would thus be seen that the situation, generally speaking, was highly satisfactory. Not many years ago, it was impossible to be certain of realizing £2 each for the shares, when they were over-shadowed by the incubus of their Sicilian Stations. They could never feel sufficiently thankful to their late Chairman, Mr. A. F. Phillips, for the way in which he had extricated the Company from its difficulties. They might congratulate themselves upon

having made great strides, in bringing the shares from this figure of £2 up to nearly £6. The Board would not sanction the dividend now proposed, unless they felt satisfied, as business men possessing particular knowledge of the gas industry, that there was sound reason for believing that this rate could be maintained.

THE FUTURE.

With regard to the future, when the Fleet returned from its duties in the Far East, he thought the Company would resume its progress, because, as he had told the shareholders twelve months ago, there was an extension of building operations in Malta. Only that day they had had a report from the Manager saying that the Government were making new roads and streets, and endeavouring to develop Malta as a health resort. The price of gas was not at all high when judged by Continental standards. On the whole, he felt that the Company's prospects were exceedingly good.

Mr. A. W. OKE seconded the adoption of the report and accounts; and it was agreed to without discussion.

DIVIDEND AND RE-ELECTIONS.

Proposed by the CHAIRMAN, and seconded by Mr. STRACHAN C. CLARKE, it was agreed:

"That a dividend of 4 p.ct., free of income-tax (making, with the interim dividend paid in December last, 7½ p.ct. for the year), be declared on the ordinary shares, and dividends of 3½ p.ct. and 3¾ p.ct., less income-tax, be declared on the first and second preference shares respectively."

Mr. A. W. Oke was re-elected a Director on the proposition of the CHAIRMAN (who spoke of his value to the Company in this position), seconded by Mr. FRANK H. JONES; and the Auditors (Messrs. William Cash, F.C.A., and Hyde C. Burton, A.C.A.) were re-appointed, on the motion of Mr. F. R. SMITH, seconded by Mr. F. W. CHURCH, F.C.I.S.

The CHAIRMAN remarked that the remuneration of the Board remained the same now as it was practically twenty years ago. Having regard, therefore, to the altered value of money, they were not receiving to-day anything like what they were in the less prosperous days of the Company. The Directors ventured to think the time had now arrived when an adjustment in this respect could fairly be made; and he was going to ask the shareholders to increase the fees of the Board by £500 a year from March 31 last, which would not more than restore the position which existed in 1908. It was something which the Company could well afford; and it was for the shareholders to say whether, in the circumstances, they would give this degree of recognition to the Directors, who had brought the Company to its present excellent position. He formally moved a resolution that the Board be given this increased remuneration.

Mr. C. H. RUTTER seconded the proposition, which was supported by Mr. W. H. DODGSON and Mr. CHURCH, and carried unanimously.

The CHAIRMAN proposed a hearty vote of thanks to the officers and staff, both at home and abroad. The ordinary trials of a gas manager were, he remarked, increased by having to work abroad. The Board felt there was no better work-sheet produced anywhere than by the small Malta Company. The results would compare with any, taking all the circumstances into consideration. The Secretary on this side was also assiduous in looking after the Company's interests.

Mr. ROBERT WILSON, as a former Chief Engineer to the Company, said he would like to second the vote, because he understood how much it was appreciated by those who were far away. The officials at Malta felt that they had a sympathetic Board, who always listened to what they had to say.

The vote was heartily passed, and acknowledged by Mr. DAUN, who said he would convey it in due course to Mr. Buckley, who he knew, together with all the Company's employees at Malta, greatly appreciated this mark of approval of the way in which they had carried out their work.

The meeting closed with a vote of thanks to the Chairman and Directors, on the proposition of Mr. DODGSON.

AN ELECTRICAL FAULT AND AN EXPLOSION AT ACTON.

Inquiry Held at the Instance of the Electricity Commissioners.

An explosion which occurred at Beaconsfield Road, Acton, and which resulted in destruction of property and loss of life, on Feb. 19, at a time when a fault was discovered in the electrical distribution system at that point, was the subject of an inquiry which was opened in the Town Hall, Acton, on Thursday, June 16. The inquiry was held by Mr. G. SCOTT RAM, M.I.E.E., and Dr. J. S. HALDANE, F.R.S., who were appointed by the Electricity Commissioners to report upon the matter under the provisions of the Electricity (Supply) Acts, 1882 to 1926. The cause of the explosion is a mystery, and has been the subject of a good deal of speculation. One suggested theory is that the fault in the electric supply system gave rise to the generation and subsequent explosion of bitumen gas, from a feeder main laid in bitumen. On the other hand, it has been suggested that coal gas might have been responsible.

Evidence was given by those who had occupied No. 1, Beaconsfield Road, Acton, which premises were destroyed by the explosion, and by others who heard the explosion and assisted in rescue work. These witnesses included Mr. A. G. Waterworth, the owner of the premises (in which he lived and carried on a retail business), who was seriously injured by the explosion. Mrs. Waterworth was also seriously injured by the explosion, and subsequently died. At the inquest the jury stated that they did not know how the explosion occurred, but they agreed that there had been no criminal neglect. They added a rider to their verdict, however, to the effect that the electric cable which had been referred to should be thoroughly overhauled.

The Gas Light and Coke Company, who supply gas in this area, were represented at the inquest, as they were also at the inquiry. Their Counsel at the inquiry were Mr. TREVOR WATSON and Mr. GEOFFREY TOOKEY.

The explosion occurred in the early hours of the morning. In their evidence, at the inquiry, as to the events which preceded it, the witnesses mentioned referred to the presence of a blue or greenish smoke, which appeared to emanate from beneath the floor in the front part of the premises. Reference was also made to a roaring sound, suggestive of the roaring of a fire, which appeared to come from beneath the pavement in the front of the premises; and it was recalled that about two years previously, when an explosion had occurred and had damaged premises on the opposite side of the road, a similar noise was noticeable. Mr. Waterworth, in his evidence, said that the gas supply to the premises was turned off at the meter at the time of the explosion. One of the witnesses referred to the smell of the smoke which had been mentioned as being more like that of decomposed pitch than of coal gas. It was also stated that, prior to the explosion, there were no fires alight, and there were no lights inside the premises.

Mr. *Waterworth*, in reply to questions by Mr. Tookey, on behalf of the Gas Light and Coke Company, said that when he was making investigations, prior to the explosion, as to the cause of the smoke, he did not smell coal gas.

Mr. *C. H. Woodman*, who was employed as a baker, at a bake-house situated about 100 yards from the destroyed premises, said that from about 1 a.m. onwards on the morning of the explosion, he had noticed a flickering of the electric lights, which went out altogether at about 3.50 a.m. He heard the explosion about seven or eight minutes after the lights went out.

Mr. *A. Richardson* (Mains Foreman of the Metropolitan Electric Supply Company) then gave evidence. He said that at 3.53 a.m. he had received a telephone message from the sub-station that there was a fault developing on the feeder laid in the road in which the premises were situated. Having given instructions for the drawing of the fuses to the affected feeder, he had got his men out, and proceeded to investigate the matter, and discovered that the explosion had occurred. The affected area was isolated, and the ground opened; and it was found that the distributor to the destroyed building was damaged.

The fault in the electric supply system was explained by means of diagrams, and the actual cables were exhibited. The diagrams showed that there was a distributor on the side of the road opposite to that of the destroyed premises, and a distributor from that running across the road and supplying the premises. This latter distributor crossed a feeder which was also laid on the opposite side of the road. The distributor was damaged at the point where it crossed the feeder, which latter was also burned-up for about 18 in. on either side of the junction. Witness' view was that a fault had occurred in the distributor crossing the road, at a point somewhere near the centre of the road, and had developed, as would be expected, towards the source of supply—*i.e.*, in the direction away from the destroyed premises—and had resulted in damage to the feeder. The distributor was bared from the point about half-way across the road to the feeder side of the road. It was laid some two or three years ago, but the feeder was laid by the Acton District Council about twenty years ago. It was a "Dialite" feeder, laid in bitumen—a method which was not now adopted. Witness referred also to an occasion, about nine months prior to the explosion, on which Mr. Waterworth had complained of smell. As a result, witness had opened the ground outside, and had made a thorough inspection. At that time he had noticed a strong smell of coal gas, which he had thought was probably due to leakage in the street; and he had asked Mr. Waterworth to report the matter to the Gas Company. When the ground was opened up after the explosion, the service cable showed no signs of a short circuit, and the distributor from the service box on that side of the road to the centre of the road was in good condition. It was from the centre of the road to the junction box on the opposite side that the distributor was burned-up.

Questioned on behalf of the Gas Company, he said that on the previous occasion, when he had opened the road as the result of the complaint of Mr. Waterworth, he had not reported the smell of gas to the Gas Company, but had left it to Mr. Waterworth, because the latter had made the complaint in the first place.

Replying to further questions, he agreed that there had been trouble with the electric mains in this neighbourhood on three occasions during the last three years. Asked if it were not a fact that the explosion which had occurred on the opposite side of the road two years previously was due to an accumulation of bitumen gas, he replied that he could not say that it was. On another occasion when trouble had occurred on other premises in Beaconsfield Road, it was caused by a short circuit due to moisture.

In the course of further questions, it was pointed out by Counsel that there was no gas main near the service box outside the destroyed premises.

In the box at the point where the service pipe joined the distributor cable there was a deposit of a substance resembling soot; and witness suggested that it was due to a blow-back of gas from the house. On the suggestion of Mr. TREVOR WATSON, it was decided that a sample of the deposit should be analyzed.

Mr. *E. Lloyd Williams* (the Electric Supply Company's District

Engineer) said that if the explosion had been due to the ignition of bitumen gas which had been generated at the point where the distributor crossed the feeder, the gas would have had to pass through a 4-in. cushion of earth, then through the duct carrying the distributor across the road, through the box at the point at which the service pipe joined the distributor, and then into the premises in which the explosion took place. When the road was opened it was found that there were three wads of clay in the duct between the box and the house; and he did not think it was possible for gas to have got into the house through those wads of clay.

Questioned by Mr. Trevor Watson, witness expressed the view that one of the wads of clay would be sufficient to prevent any considerable escape of gas. Asked if he agreed with Mr. Richardson's theory that the deposit in the box was due to a blow-back of gas from the house, he said that was all he could reasonably suggest.

Mr. Trevor Watson thereupon pointed out that the wads of clay were in the duct between the house and the box, and witness had already admitted that each one of those wads would be sufficient to prevent a considerable escape of gas.

Mr. *F. Stainton* (the Sub-Station Engineer) gave evidence as to the steps taken at the sub-station when the fault on the feeder became apparent. He said he had telephoned to Mr. Richardson, and, at Mr. Richardson's request, had drawn the fuses to the affected feeder.

Mr. Trevor Watson, in the course of cross-examination, put questions with regard to the telephone conversations which witness had had with Mr. Richardson, and the sequence of events at the time the fault was discovered. Counsel pointed out that one of the pertinent facts which would have to be elicited at the inquiry was whether the explosion occurred before or after the fault had developed in the cable. The evidence showed, he said, that the lights in the bakehouse at which Mr. Woodman was employed went out when the fuses at the station were withdrawn; and it was obvious that the fault happened before the explosion occurred.

The evidence on behalf of the Electric Supply Company having been completed,

The Chairman asked whether witnesses were to be called on behalf of the Gas Light and Coke Company.

Mr. Tookey replied that he was not proposing to call any witnesses, unless the Court thought otherwise. He did not think the Gas Company was concerned.

The Chairman said there was a suggestion that the Company's gas had caused the explosion.

Mr. Tookey replied that he did not know that the suggestion was made seriously, but lest there should be the slightest doubt, he would call one or two witnesses.

Mr. Haldane pointed out that the suggestion had been made at the inquest.

Mr. Tookey agreed that suggestions had been made in the early stages, but he did not think they were made seriously at this inquiry. He was prepared to call witnesses, however.

At this stage the inquiry was adjourned until Monday, June 20; it being the intention that the road at the point where the trouble occurred should be opened, and that the Court, and the representatives of the interests concerned, should carry out an inspection before the resumption of the proceedings.

COAL TRADE REPORTS.

From Our Own Correspondents.

NORTH-EAST COAST.

While the general position of the trade cannot be said to have improved, there are a few encouraging features even in the general gloom. A large share of a big Swedish railway contract has been obtained for Northumberland and Durham. This has been taken by exporters at c.i.f. prices which appear to leave very little for the collieries. But the fact that the order has gone very largely for English coal is an encouraging sign. The French licence scheme is also now regarded more calmly. It is known that permits for a good proportion of the normal quantity have already been granted over the next few months, and it is felt that in some parts of France it will not be found easy to do without British coal.

Further notices to men have had to be given, chiefly in connection with the reduction of working at some collieries to one shift, though others are closing down entirely. Should there be any increase in the volume of trade, the reduction of output would naturally be reflected in prices, especially as there is a certain amount of coal sold by merchants and exporters which they have not covered. There has, perhaps, been rather more inquiry during the past week, but there are still far too few orders to go round.

Wear Special and best quality gas makes have not been generally firm at 16s. 6d. to 16s. 9d., f.o.b., and seconds are plentiful at 14s. to 14s. 6d. Coking coals are in a better position than they were a few weeks ago, and, though nominally unchanged at 14s. to 14s. 6d., they are firmer at these prices. Durham unscreened bunkers are 15s. 3d. to 16s. 3d. f.o.b., for best sorts, according to place of shipment; others are 14s. to 14s. 6d. f.o.b.

Gas coke for shipment is steady at 19s. 6d. f.o.b.

YORKSHIRE AND LANCASHIRE.

Gas coals in Yorkshire and Lancashire are being quoted under contract for twelve months at "cut" figures; and although some stabilized rates have been fixed by certain of the supplying collieries, in many instances these have been discounted.

The house coal trade is passing through its usual summer phase, and consumers still purchase in small quantities. Reduced prices operate in accordance with the accumulated stocks at each particular colliery.

The industrial market does not improve, and pits generally are working from three to four days per week. Furnace coke has also weakened considerably, a rapid change having taken place during the past six or seven weeks.

The export market shows a better tone in respect of inquiries, but not as to any increased business. Evidently with the very low figures now operating there may be some slight improvement shortly.

The following are the Humber bunker and export prices, f.o.b. usual shipping ports: South Yorkshire—Hards, Association, 15s. 6d. to 15s. 9d.; screened gas coal, 15s. 9d. to 16s.; washed trebles, 16s. to 16s. 9d.; washed doubles, 15s. 9d. to 16s.; washed singles, 15s. 3d. to 15s. 9d.; washed smalls, 14s. to 14s. 3d.; rough slack, 13s. to 13s. 6d.; smithy peas, 18s. to 19s. per ton. West Yorkshire—Hartleys (f.o.b. Goole), 14s. 9d. to 15s. 6d.; screened gas coal, 15s. to 16s.; washed trebles, 15s. to 16s.; washed doubles, 15s. to 16s.; washed singles, 15s.; washed smalls, 13s. 9d. to 14s. 3d.; unwashed trebles, 14s. 9d. to 15s. 6d.; unwashed doubles, 14s. 6d. to 15s.; rough slack, 13s. to 13s. 6d.; coking smalls, 12s. 6d. to 13s. per ton. Derbyshire and Nottinghamshire—Top hards 16s. to 19s.; washed doubles, 16s. to 16s. 6d.; washed singles, 16s. to 16s. 6d.; washed smalls, 14s. to 15s.; unwashed doubles, 15s. to 16s.; rough slack, 13s. to 13s. 9d. per ton. Yorkshire, Derbyshire, and Nottinghamshire—Screened steam coal, 14s. 6d. to 15s.; gas coke, 20s. to 24s.; furnace coke, 17s. to 18s. per ton.

MIDLANDS.

Negotiations for supplies of gas coal over the ensuing year are proceeding slowly. A number of gas undertakings have not yet made their contracts. They have good stocks, so that even spot lots at special prices are receiving little attention, and they are fighting for best terms. The difference of a few coppers in quotations is matter for long and stubborn bargaining. Fearful lest they should overstand their market, collieries have given ground till contracts have been entered into at 16s. to 17s. for screened coal and 1s. less for washed nuts.

Industrial and domestic coal are in over-supply, and there has been a further curtailment of work at the pits. Large numbers of miners are becoming chargeable to the unemployment fund. Selling prices slumped so early in the spring that there is no room for further reductions with many of the concerns on an uneconomic basis.

Revisions effected since May have been directed chiefly to levelling out irregularities. Coal for dealers' yards is selling down to 12s. 6d. at pithead, but the radius of absorption is limited, of course, by transport costs. So low a price is not common to all districts. High-grade household coals are steady. Some merchants report that a few of their customers are putting coal into their cellars against the autumn.

CURRENT SALES OF GAS PRODUCTS.

The London Market for Tar, Tar Products, and Sulphate.

London, *June* 20.

There is more interest being displayed in pitch. For next season's delivery makers' ideas of value are not below 77s. 6d. to 80s. per ton f.o.b. makers' works.

Creosote is steady at 8¾d. to 9d. per gallon.

Pure benzole is about 1s. 7d. per gallon, pure toluole about 1s. 10d. per gallon, and 95/160 solvent naphtha about 1s. 5d. to 1s. 6d. per gallon.

Tar Products in the Provinces.

June 20.

The average values of gas-works products during the week were: Gas-works tar, 55s. 9d. to 60s. 9d. Pitch—East Coast, 72s. 6d. to 77s. 6d. f.o.b. West Coast—Manchester, 70s. to 77s.; Liverpool, 72s. 6d. to 77s. 6d.; Clyde, 75s. to 77s. 6d. Benzole, 90 p.ct. North, 1s. 3d. to 1s. 4d.; crude, 65 p.ct. at 120° C., 10½d. to 10¾d., naked, at makers' works; 50-90 p.ct. naked, North, 1s. 4d. to 1s. 5d. Toluole, naked, North, 1s. 4½d. to 1s. 5½d. nominal. Coal-tar crude naphtha, in bulk, North, 7½d. to 8d. Solvent naphtha, naked, North, 1s. 0½d. to 1s. 1¾d. Heavy naphtha, North, 1s. to 1s. 1d. Creosote, in bulk, North, liquid, 7½d. to 7¾d.; salty, 7½d. to 7¾d.; Scotland, 7½d. to 7¾d. Heavy oils, in bulk, North, 9d. to 9½d. Carbolic acid, 60 p.ct., 2s. 4d. prompt. Naphthalene, £11 to £14; salts, £5 to £5 10s., bags included. Anthracene, "A" quality, 2½d. per minimum 40 p.ct., purely nominal; "B" quality, unsaleable.

CONTRACTS OPEN.

Coal.

Tenders for coal are invited by the Denton Gas Committee. [See advert. on p. 944.]

The Gloucester Gas Light Company are inviting tenders for the supply of coal. [See advert. on p. 944.]

The Harwich Gas and Coke Company are inviting tenders for the supply of gas coal. [See advert. on p. 944.]

Meters.

The Denton Gas Committee are inviting tenders for the supply of ordinary and prepayment gas meters. [See advert. on p. 944.]

Pipes, Tubing, Fittings, &c.

Tenders for the supply of above are invited by the Denton Gas Committee. [See advert. on p. 944.]

The Marple Gas Committee are inviting tenders for the supply of main pipes, syphons, bends, tees, &c. [See advert. on p. 944.]

"Dri-Gas" plants, manufactured by Messrs. W. C. Holmes & Co., Ltd., are in operation at Taunton and Bristol, and we understand that others will shortly be started-up at Tunbridge Wells, Weston-super-Mare, and Portsmouth. Further plants are under construction for the Gas Light and Coke Company, Bournemouth, Long Eaton, and Colne.

STOCK MARKET REPORT.

THE anticipated improvement in business after the long account did not materialize last week, and transactions on the Stock Exchange were comparatively few. Markets were also affected by the anxiety over the monetary situation, and gilt-edged stocks had to contend with the influence of the European political troubles, particularly the demands made in Poland by the Soviet Government. While Home Government stocks were in consequence depressed, the 5 p.ct. War Loan remained firm throughout.

The feature of the Foreign Market was the persistent decline of French Government bonds, consequent on the rebuff to the Ministry over the match monopoly. The issue by the National Mortgage Bank of Greece was successfully floated, the amount offered being heavily oversubscribed. Among the many new issues published during the week-end were the Republic of Estonia £700,000 7 p.ct. sterling bonds at 94½, and the Lancashire Electric Light and Power Company's £1,000,000 5 p.ct. redeemable debenture stock at 95.

In spite of the general dullness the popular shares in the Industrial Market attracted a good deal of attention, Artificial Silks being most prominent. In the Rubber Market the sharp fall in the price of the commodity, which fell to the lowest level (1s. 4½d.) for over two years, caused shares to slump badly; but there was some improvement towards the close of the week.

The Gas Market was not overburdened with business last week, but prices remained steady. It will be seen by the Table that the stocks of no less than eight companies were marked up 1 point. This is due to the fact that the margin of 5 points existing hitherto between the jobbers' nominal buying and selling prices has in these cases been restricted to 3 points. Increases were also recorded in Gas Light ordinary ½ point, Primitiva 6d. share, and Tottenham "B" 1 point. There were the usual half-yearly ex-interest reductions. Two additions have been made to the Table—viz., Barnet 7 p.ct. ordinary and British 5 p.ct. debenture; while the Uxbridge 5 p.ct. Maidenhead stock has been merged with the Uxbridge ordinary stock.

The following transactions were recorded during the week:

On Monday, Alliance and Dublin 85, Bournemouth "B" 12⅞, British 108½, 5 p.ct. debenture 98, Commercial 4 p.ct. 88⅝, Continental Union 35 11/16, 35½, Croydon sliding-scale 98, 98½, Gas Light and Coke 87¼, 87⅜, 88, 4 p.ct. preference 76½, 77¼, 5 p.ct. debenture 100¼, 100⅞, Imperial Continental 138½, 139, Primitiva 14s. 7½d., 14s. 9d., South Metropolitan 101½, 3 p.ct. debenture 59, Tottenham "B" 93½, 93¾. Supplementary prices, Croydon 7½ p.ct. preference 102, 102½, Gas Light and Coke, Brentford 7½ p.ct. mortgages 104.

On Tuesday, Aldershot 4 p.ct. preference 69, British 4 p.ct. debenture 76½, Continental Union 36½, European 6⅞, Gas Light and Coke 87⅝, 88, 88¼, 88⅜, 3½ p.ct. 60½, 3 p.ct. debenture 59, 5 p.ct. debenture 101, Imperial Continental 138½, 139, Primitiva 14s. 6d., 14s. 9d., South Metropolitan 101¼. Supplementary prices, Liverpool 5 p.ct. 84, 85¼, Yorktown and Blackwater new 5 p.ct. preference 89.

On Wednesday, Continental Union 37, European 6 13/16, Gas Light and Coke 88, 3 p.ct. debenture 60, 5 p.ct. debenture 100⅝, 101, Imperial Continental 138½, 139, 139½, 140, Primitiva 14s. 5¾d., 14s. 6d., 14s. 10½d., South Metropolitan 101, 101⅞, 102, South Suburban 5 p.ct. debenture 95. Supplementary prices, Barnet 5 p.ct. debenture 97½, Yorktown and Blackwater new 5 p.ct. preference 88⅜, 89.

On Thursday, Alliance and Dublin 85, 85¼, European 6 13/16, Gas Light and Coke 88, 88⅛, 4 p.ct. preference 76½, Imperial Continental 138½, 139, 139½, Oriental 101, 102, Primitiva 14s. 6d., 14s. 9d., 14s. 10½d., South Metropolitan 101½.

On Friday, Alliance and Dublin 85¼, 85½, Brighton and Hove 6 p.ct. 106½, Commercial 3½ p.ct. 86⅜, European 6 11/16, 6 13/16, Gas Light and Coke 88, 88⅛, 88⅜, 3½ p.ct. 60½, 60⅝, 61, 4 p.ct. preference 76½, 3 p.ct. debenture 38, 5 p.ct. debenture 99⅛, Primitiva 14s. 9d., South Metropolitan 102, 3 p.ct. debenture 59½. Tottenham "B" 92½. Supplementary prices, Hertford 10 p.ct. 14, 14½. Southgate and District additional 100.

In Lombard Street supplies of money were abundant in the short loan market; and after 3½ p.ct. had been quoted, both old and new advances were offered down to 3 p.ct. Discount quotations remained firm, however, assisted by the weaker tendency of the American exchange and the further slight rise in the Treasury Bill rate, which averaged £4 7s. 7·26d. p.ct.

In the Foreign Exchange Market Sterling on New York declined to 4.85 5/16; and the Belgian and Dutch rates moved against this country to 34.96 and 12.12 1/16 respectively. French francs remained at 124, and Spanish pesetas closed slightly higher at 28.34.

Silver re-acted sharply after the recent improvement, and the price fell to 26½d. per oz. No Gold was available at the end of the week, and the price remained nominally at 84s. 11½d. per oz.

The Bank Rate is 4½ p.ct., to which it was reduced from 5 p.ct. on April 21. Bankers' deposit rates are 2½ p.ct. The deposit rates of the discount houses are 2½ p.ct. at call and 2¾ p.ct. at notice.

Issue.	Share.	When ex-Dividend.	Dividends. Prev. Hf.Yr	Dividends. Last Hf. Yr.	NAME.	Quotations. June 17.	Rise or Fall on Week.	Transactions. Lowest and Highest Prices.
£			%p.a.	% p.a.				
171,978	Stk.	Feb. 10	5	5	Aldershot 5 p.c. max. C.	70—73	..	..
222,999	,,	,,	4	4	Do. 4 p.c. Pref.	68—71	..	69
1,551,868	,,	Apl. 7	6½	7	Alliance & Dublin Ord.	84—87	..	85—85½
374,000	,,	Jan. 13	4	4	Do. 4 p.c. Deb.	65—68	..	..
522,554	,,	—	—	—	Barnet Ord. 7 p.c.	101—104	..	..
200,000	1	Apl. 28	1/7½	1/7½	Bombay, Ltd.	1—1½	..	..
170,000	10	Mar. 10	8½	8½	Bournemouth 5 p.c.	12½—13½	+½	..
600,050	10	,,	7	7	Do. B 7 p.c.	12½—13½	+½	13⅜
975,000	10	,,	6	6	Do. Pref. 6 p.c.	11—11½	..	..
80,000	Stk.	Jan. 13	3	3	Do. 3 p.c. Deb.	58—66	..	..
162,095	,,	,,	4	4	Do. 4 p.c. Deb.	75—78	..	..
357,900	,,	—	—	—	Brighton & Hove 6 p.c. Con.	105—108	..	106½
341,800	,,	—	—	—	Do. 5 p.c. Con.	92—95	+1	..
1,887,500	,,	Feb. 24	5	5	Bristol 5 p.c. max.	88½—89⅝	..	..
865,000	,,	Mar. 24	6	7	British Ord.	106—109	..	108½
100,000	,,	Dec. 30	7	7	Do. 7 p.c. Pref.	113—117	..	..
130,000	,,	,,	4	4	Do. 4 p.c. Red. Deb.	78—80	..	76½
200,000	,,	—	—	—	Do. 5 p.c. Red. Deb.	96—98	..	98
100,000	10	May 26	6	8	Cape Town, Ltd.	7½—8½*	..	..
100,000	10	Apl. 28	4½	4½	Do. 4½ p.c. Pref.	6—7	..	..
150,000	Stk.	Dec. 30	4½	4½	Do. 4½ p.c. Deb.	70—75	..	..
696,880	,,	Feb. 24	6	6	Cardiff Con. Ord.	99—103	..	..
237,880	,,	Dec. 30	7½	7½	Do. 7½ p.c. Red. Deb.	100—103	..	..
157,150	,,	Feb. 24	5	5½	Chester 5 p.c. Ord.	86½—91½b	..	..
79,185	1	Apl. 28	†2/-	†2/-	Colombo Ltd. Ord.	26/—28/-	..	..
24,495	1	,,	1/4½	1/4½	Do. 7 p.c. Pref.	20/—22/-	..	..
831,490	1	Apl. 7	1/9½	1/9½	Colonial Gas Assn. Ld. Ord.	24/6—26/6	..	..
178,900	1	,,	1/7½	1/7½	Do. 8 p.c. Pref.	20/—22/-	..	..
1,518,280	Stk.	Feb. 24	5½	5½	Commercial 4 p.c. Cap.	87—90	..	88½
560,000	,,	,,	5/8/4	5/8/4	Do. 3½ p.c. Cap.	85—88	..	86½
475,000	,,	June 16	3	3	Do 3 p.c. Deb.	55—58*	−1	..
800,000	,,	Sept. 30	†2	†1	Continental Union, Ltd.	35—38	+2	35 11/16—37
200,000	,,	Mar. 10	7	7	Do. 7 p.c. Pref.	79—82	..	..
787,583	,,	Mar. 10	6½	6½	Croydon sliding scale	96—99	..	98—98½
408,100	,,	,,	5	5	Do. max. div.	77—80	..	..
492,270	,,	Feb. 24	6	9	Derby Con.	104—106c	..	..
55,000	,,	Dec. 30	4	4	Do. Deb.	73—75c	..	..
209,000	,,	Mar. 10	5	5	East Hull Ord. 5 p.c.	76—80	..	..
50,000	,,	June 16	5	5	Eastbourne 5 p.c. Deb.	90—95*	−2	..
1,002,180	10	Mar. 24	†3	†3	European, Ltd.	6¼—7⅛	..	6 13/16—6 15/16
18,747,460	Stk.	Feb. 10	5/1/4	5	Gas Light & Coke 4 p.c. Ord.	87—89	+½	87½—88½
2,600,000	,,	,,	3½	3½	Do. 3½ p.c. max.	59—61	..	60½—61
4,187,020	,,	,,	4	4	Do. 4 p.c. Con. Pref.	76—78	..	76½—77½
5,502,820	,,	June 16	3	3	Do. 3 p.c. Con. Deb.	57—59*	−1	58—60
181,315	,,	,,	6	6	Do. 6 p.c. Br'if'd Rd. Db.	100—103*	−1	..
1,642,770	,,	,,	5	5	Do. 5 p.c. Red. Deb.	98—100*	−1	99½—101
42,000	,,	—	7½	7½	Do. 7½ p.c. Ilford Deb.	..	..	..
82,500	,,	Mar. 10	6½	6½	Hastings & St L. 5 p.c. Conv	90—92	..	..
258,740	,,	,,	5½	5½	Do. 3½ p.c. Conv.	67—72	..	..
70,000	10	Apl. 28	†10	†10	Hongkong & China, Ltd.	12—13	..	..
178,200	Stk.	Mar. 10	5	5	Hornsey Con. 3½ p.c.	67—69	..	..
1,976,000	,,	May 12	10	10	Imperial Continental Cap.	137—141	..	139½—140
223,130	,,	Feb. 10	3½	3½	Do. 3½ p.c. Red. Deb.	69—71	..	..
285,242	,,	Mar. 10	6½	6½	Lea Bridge 5 p.c. Ord.	94—97	+1	..
2,145,907	,,	Feb. 24	5½	5½	Liverpool 5 p.c. Ord.	84—85b	..	84½
600,000	,,	Sept. 30	7	7	Do. 7 p.c. Red. Pref.	103—105b	+1	103
165,786	,,	Feb. 24	9	8	Maidstone 5 p.c. Cap.	110—115	..	..
63,480	,,	June 16	3	3	Do. 3 p.c. Deb.	50—55*	−2	..
75,000	5	June 16	†7	†8	Malta & Mediterranean	5—5½*	−½	..
541,920	Stk.	May 26	†5	†7	Montevideo, Ltd.	89—92	+1	..
2,061,815	,,	Feb. 24	5	5	Newcastle & Gateshead Con.	74—74½d	−½	..
360,929	,,	,,	4	4	Do. 4 p.c. Pref.	68—69d	..	..
691,705	,,	Dec. 30	3½	3½	Do. 3½ p.c. Deb.	68—69d	..	..
131,785	,,	—	—	—	North Middlesex 6 p.c. Con.	91—95	..	..
300,000	,,	Apl. 28	9	7	Oriental, Ltd.	99—102	+1	101—102
188,120	,,	Dec. 30	7½	7½	Plym'th & Ston'house 5 p.c.	105—110	..	..
414,500	,,	Feb. 24	7½	7½	Portsm'th Con. Stk. 4 p.c. Std.	102—105	+1	..
236,782	,,	,,	5	5	Do. 5 p.c. max.	76—79	..	..
2,389,909	1	—	—	—	Primitiva Ord.	14/6—15/6	+·/6	14/5½—14/10½
282,200	100	June 1	4	4	Do. 4 p.c. Red. Deb.	84—86*	..	..
600,000	Stk.	Jan. 27	4	4	Do. 4 p.c. Red. Deb. 1911	70—72	..	..
434,963	,,	Dec. 30	—	4	Do. 4 p.c. Cons. Deb.	70—72	..	..
150,000	10	Mar. 24	6	6	San Paulo 6 p.c. Pref.	7½—7⅝	..	..
125,000	50	July 1	5	5	Do. 5 p.c. Red. Deb.	47—50	..	..
270,000	Stk.	Mar. 24	5⅜	5⅜	Sheffield A	98—100	..	..
419,968	,,	,,	5⅜	5⅜	Do. B	98—100	..	..
1,047,000	,,	,,	5⅜	5⅜	Do. C	98—100	..	..
90,000	10	May 26	4	6	South African	4—6*	..	..
6,609,895	Stk.	Feb. 24	5	7	South Met. Ord.	100—102	..	101—102
1,895,445	,,	Jan. 13	3	3	Do. 3 p.c. Deb.	57—60	..	59—59½
734,000	,,	Mar. 10	6½	6½	Do. 6½ p.c. Red. Db.	99—101	..	..
91,500	,,	Feb. 24	8½	8½	South Shields Con.	104—106d	..	..
1,243,795	,,	Mar. 10	6½	6½	South Suburban Ord. 5 p.c.	103—106	..	..
368,837	,,	June 16	5	5	Do. 5 p.c. Deb.	92—95*	−2	95
647,740	,,	Mar. 24	5	5	South'mpton Ord. 5 p.c. max	74—77	..	..
121,275	,,	Dec. 30	4	4	Do. 4 p.c. Deb.	70—73	+1	..
250,000	,,	Feb. 24	7	7	Swansea 7 p.c. Red. Pref.	100—102	..	..
200,000	,,	June 16	6½	6½	Do. 6½ p.c. Red. Deb.	100—102*	−2	..
120,000	,,	Feb. 24	7½	7½	Tottenham District A 5 p.c.	107—110	+1	..
882,275	,,	,,	6½	6½	Do. B 3½ p.c.	91—94	+1	92½—93½
150,000	,,	,,	5½	5½	Do. 5½ p.c. Pref.	97—100	..	..
181,255	,,	June 16	4	4	Do. 4 p.c. Deb.	70—73*	−2	..
268,251	,,	Mar. 10	5	5	Tynemouth Con. and New	71—72d	..	..
238,094	,,	Mar. 10	6½	6½	Uxbridge, Maidenhead, & Wycombe 5 p.c.	85—90	..	..
88,330	,,	,,	5	5	Do. 6 p.c. pref.	83—88	..	..
30,000	,,	Mar. 10	8½	8½	Wandsworth, Wimbledon, and Epsom— Wandsworth A 5 p.c.	120—125	..	..
256,686	,,	,,	7	7	Do. B 3½ p.c.	102—107	..	..
432,535	,,	,,	5/19/0	5/19/0	Do. C and New	90—95	..	..
352,000	,,	,,	6⅝	6⅝	Wimbledon 5 p.c.	98—103	..	..
98,000	,,	,,	7½	7½	Epsom 5 p.c.	103—108	..	..
88,416	,,	Dec. 30	3	3	3 p.c. Deb.	54—57	..	..

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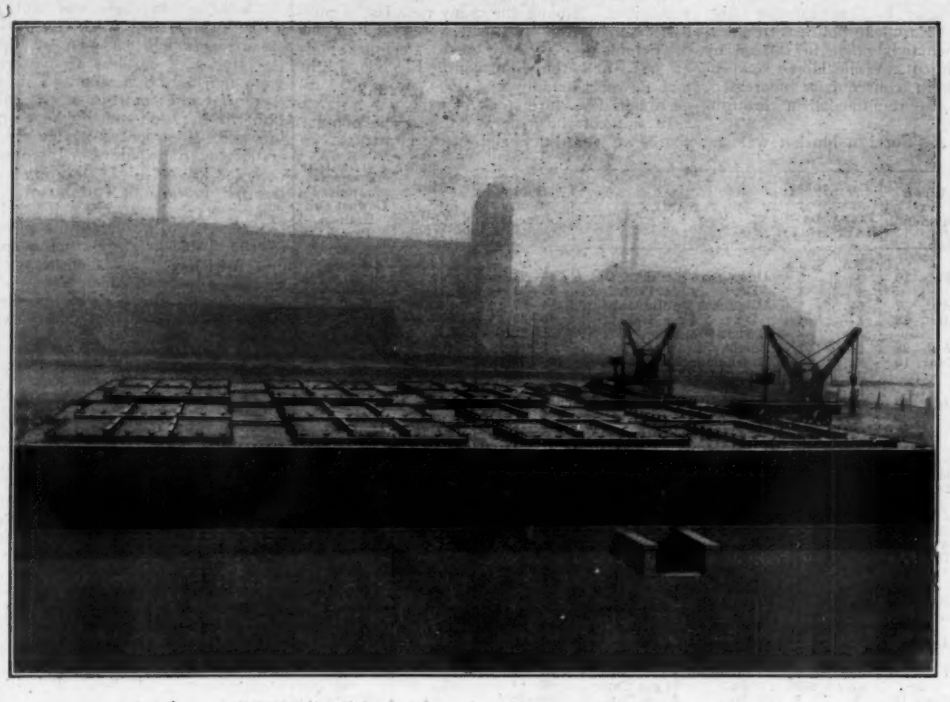

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